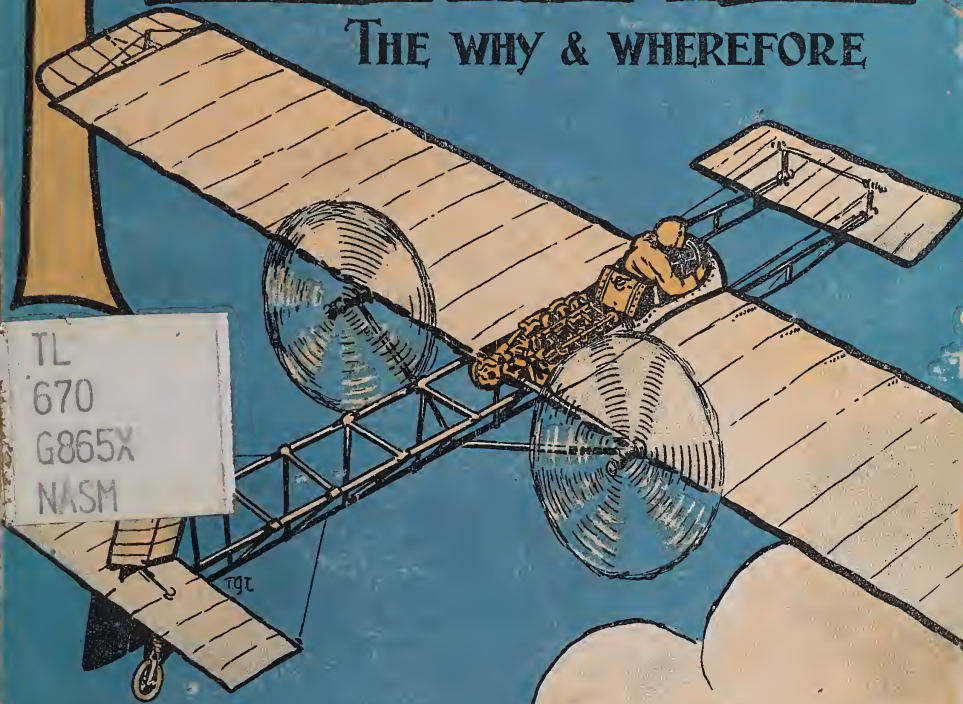


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FLYING

THE WHY & WHEREFORE

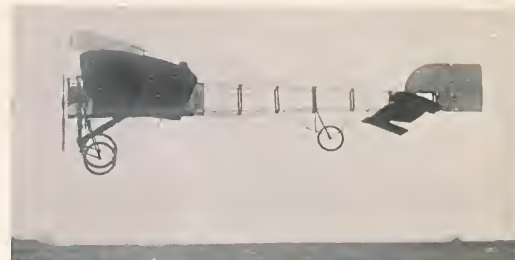
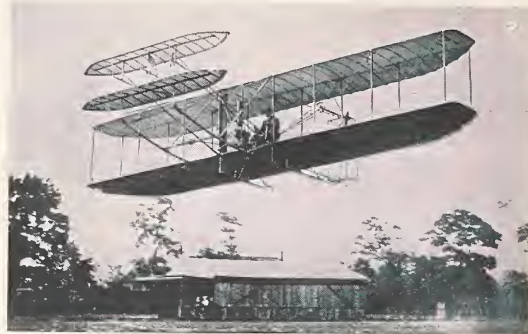
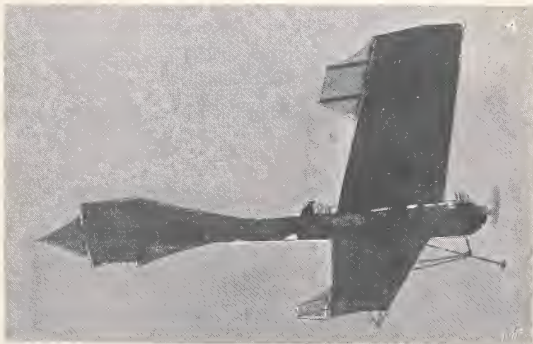
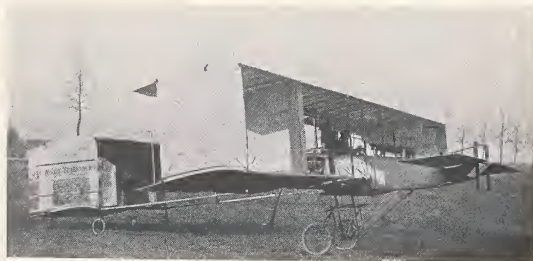


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2. WILBUR WRIGHT'S BIPLANE.—The first machine to carry a man for a mile.
3. BLERIOT'S 1908 MONOPLANE.—Bleriôt was the second machine to make a cross-country journey, and in the course of this journey it alighted and rose again by its own power. The Cross Channel machine is much of this type.
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FLYING

THE WHY AND WHEREFORE.

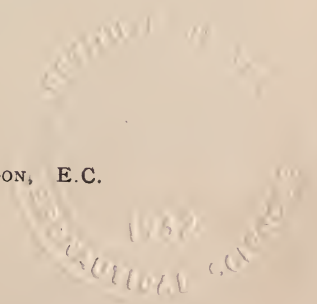
2^d Edition

BY

"AERO-AMATEUR."

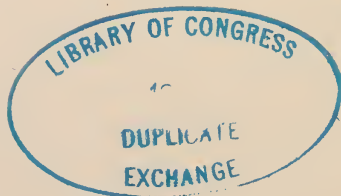
"THE AERO,"

20, TUDOR STREET, LONDON, E.C.



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With the compliments of the author,
Chas. G. Grey

INTRODUCTORY.

THE contents of this book were originally written as a series of articles for *The Autocar*, but it was found that the length thereof would involve spreading the publication of them over several months. Public interest in Flying has increased so rapidly during the present year that it was thought better to publish the whole series at once in book form. Also there is the fact that *The Autocar* has now thrown off a satellite, *The Aero*, which is dealing exclusively with aeronautic subjects, and I hope that this book may give all readers of *The Aero* who are novices an opportunity to acquire forthwith a knowledge of the elementary principles of flying as set forth by an amateur for amateurs. I have therefore expanded various chapters so as to go somewhat more deeply into the subjects with which they are concerned, and I have added a series of diagrammatic sketches of the chief machines at present existing, so that my readers may more easily follow the points raised in the book itself. The frontispiece shows photographs of eight of the most successful machines in actual use.

The book does not profess to be a handbook of flying, or a record of what has been done in the development of flying. It is simply an explanation of the why and wherefore of the various machines which have flown, of the theories on which their construction has been carried out, and it contains as well certain deductions from those theories which may have important bearings on the flying machines to be constructed in the near future. All this has been set forth in the simplest possible way, so that the man without engineering or mathematical training may be able to follow the various points of existing machines and the development of the machines of the future. It is essentially a book for the "man in the street," though I hope it will not be without its value to those who are about to make, or are actually making, machines of their own.

INTRODUCTORY. (Continued).

I have dealt exclusively with flying machines, or aeroplanes, as they are more commonly called, because I believe them to be the only aerial locomotives with a great future, but I should like my readers to realise that, so far as the immediate safety of this country is concerned, we are foolishly neglectful of the possibilities of the dirigible balloon. Probably in ten years time the dirigible will be as obsolete as a wooden battleship, but in the meantime we are at the mercy of any power which possesses two or three decent dirigibles. At present our *entente* with France makes us feel perfectly safe, so far as that country is concerned, but nevertheless London is to-day absolutely at the mercy of the French dirigibles. Given a calm day, such as those which bring December fogs, and any of the French dirigibles could be inflated at Calais or Dunquerque, could reach London in a few hours, and, hidden above the fog, could do considerable damage to the city while remaining unhurt themselves. Similarly a French dirigible inflated at Dieppe could make equally short work of the Dockyard at Portsmouth; and though the guns on Portsdown might hit it, the said guns would probably do more damage to the yard, over which their shells would burst, than they would do to the dirigibles floating immediately overhead. I think Captain F. W. Marriott, of the Aerial League, will confirm this view, for it is he who has done most to impress me with the immediate possibilities of the dirigible. The French aeronauts know they hold us in the hollow of their hands, but they are much too clever to show what they can do by making a trial trip from Calais to London, though such a practical demonstration is the thing needed above all others to wake this country up.

As for Germany, I believe the existing Zeppelin could reach London from the German frontier, under favourable conditions, by flying across Belgium, or at any rate an airship of that type will certainly be able to do so in a year or two. However, London, after all, is not so important as our dockyards, for if they were broken up our fleet would soon become helpless. The whole country would

INTRODUCTORY. (Continued).

be starved out in six weeks if we once lost command of the sea. Disable Devonport, Portsmouth, Chatham, and Woolwich, and we are at the mercy of any invading army. France or Germany can disable us in that way at a cost of, say, £1,000,000 spent on dirigibles, unless we in this country raise an armament superior to theirs.

The only efficient weapon against the dirigible balloon is a flying machine that can fly faster than the dirigible. Guns cannot hit a moving speck in the sky at 2,000ft. or 3,000ft., and the dropping bits of their shells will do more damage below than aloft. If they did, by sheer luck, bring a dirigible down, its fall would damage the place on which it fell. Against that, a fast flying machine could out-manceuvre a dirigible, could drive it clear of human habitations, and then sink it. But this state of affairs is not likely to arrive for a good many years, and meantime we are at the mercy of the dirigibles. Therefore it behoves us, in self-defence, at once to build dirigibles as good as those of any other nation, and in the meantime to turn our best inventive faculties on to the perfection of flying machines. The building of dirigibles is an affair which only Governments or very rich companies can handle, whereas any moderately rich man can afford a flying machine, which is even now as cheap as a good car, and will soon be very much cheaper. I trust, therefore, that the development of flying machines may progress rapidly through the enterprise of private owners, even if the Government be slow in acting.

The Government certainly bestirred itself to the extent of negotiating abroad for a second-hand gasbag for the working parts of a dirigible made experimentally at Aldershot. Then came the *Morning Post* National Airship Fund, and the Government was thus shamed into consenting to buy a second dirigible if the *Morning Post* would buy the first. There is also a rigid dirigible being built at Barrow-in-Furness, so we are gradually waking up.

To-day there is no doubt that there are a thousand people keenly interested in the subject for every one person there was early in the year. For this sudden access of

interest the excitement over the Channel Flight is largely responsible, and the credit for the booming of the Channel Flight is directly due to Lord Northcliffe and the *Daily Mail*. For years the press of this country has shamefully and studiously neglected the mere existence of such a thing as aeronautic science. Since the awakening of the daily press it has certainly done its best to make up for lost time. Further, accounts of flying performances in the daily papers have been wonderfully accurate, considering that they have been written purposely to stir up the interest of the people, and that there must have been a great temptation to tickle the ears of the groundlings with blatant sensationalism. Everyone interested in flying owes the daily papers a debt of gratitude ; the older hands for stirring up public interest in the object of their devotion, and the newcomers for directing their attention to this fascinating subject. Much credit is also due to the *Morning Post* for its patriotic efforts in raising the National Airship Fund, and so saving this country from its backward position in the matter of aerial armament. Flying is now in popular favour. I trust that it may, ere long, become a matter of our daily existence.

As to this book itself, I have stuck to the word "aeroplane" because it has been adopted into the language, in spite of its actual meaning being quite different from its accepted meaning. Also I have used the word "plane" to denote the supporting surfaces of the machine for the same reason. "Plane surface" means a perfectly flat surface, but I fear the theoretical meaning will have to give way to that popularly accepted. Similarly, Professor Langley's word "aerodrome"—meaning "air runner"—for a flying machine will always mean a flying ground, on the analogy of "hippodrome," so far as the general public are concerned. Apart from these, I have preferred to adopt Mr. Lanchester's terminology, which has the advantage of being distinctive and comparatively apposite.

If any of my readers wish to controvert any of my statements, I am sure the correspondence columns of *The Aero* will be open for them to do so ; and if any

INTRODUCTORY. (*Continued*).

readers wish for further information, or wish to suggest any expansion of certain points in future articles on flying, a letter to *The Aero*, 20, Tudor Street, E.C., will reach the writer.

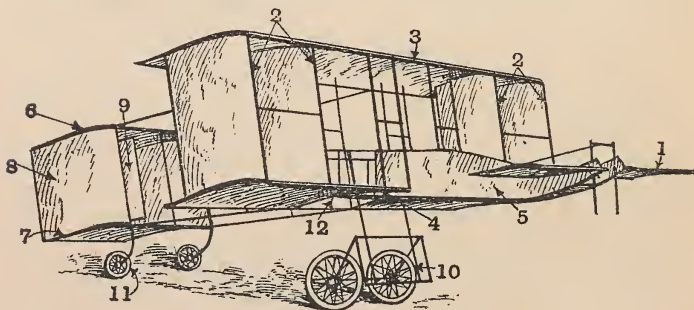
The Aero, as I have already indicated, is the new rd. weekly paper which the proprietors of *The Autocar* have founded to deal exclusively with aero-motors and aeronautics, as it was found impossible to give sufficient space to the subject in the columns of the Leading Motor Paper, for its pages are even now barely able to hold the amount of purely autocar matter with which it is necessary for it to deal. As a contributor to the columns of *The Aero* I may perhaps be allowed to add that not only is it devoted to the subject of flying, but it is edited in such a way that, while it is of the greatest possible use, both technically and as a source of news, to the practical aviator, it is full of interest and perfectly easily understood by anyone who is at present absolutely ignorant of the science and who wishes to learn.

“AERO-AMATEUR.”

PARTS OF EXISTING MACHINES.

The illustrations of the eleven machines hereafter will give my readers a practical idea of the functions of their various parts, and of the meaning of the various terms I have used in the body of this book. It will be understood that these sketches are more or less diagrammatic, but comparison with three of the photographs which appear in the frontispiece will show that the sketches have been kept fairly close to the effect seen when the machine is in actual use.

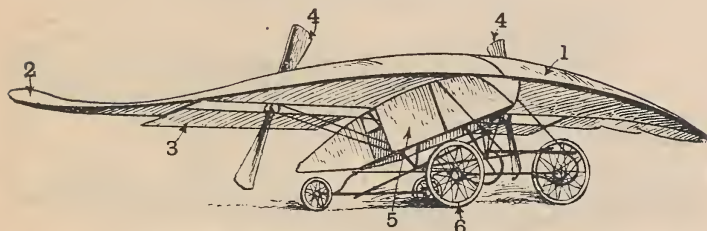
(1) THE VOISIN BROS. BIPLANE.



1. Single plane front damper. 2. Vertical planes to give directional sense and lateral stability. 3. Upper main plane. 4. Lower main plane. 5. Body. 6. Upper horizontal tail plane. 7. Lower horizontal tail plane. 8. Vertical tail planes. 9. Rudder, in middle of tail. 10. Main landing wheels. 11. Tail wheels. 12. Position of single propeller.

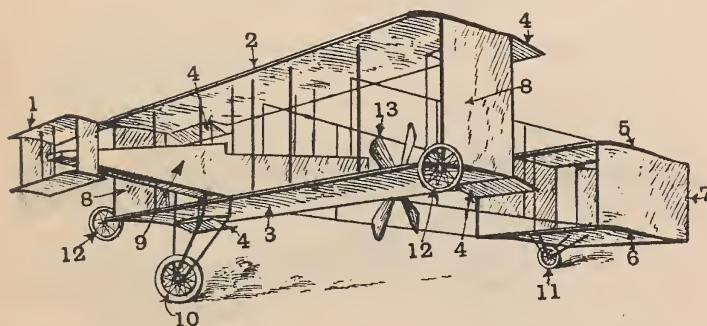
PARTS OF EXISTING MACHINES (Continued).

(2) MR. JOSE WEISS'S MONOPLANE.



1. Main plane, shaped like the two wings of a bird if joined together at the roots. 2. Tilted tips, to give directional sense and lateral stability. 3. Ailerons, for steering combined with lateral stability in turning. 4. Propellers. 5. Body for driver. 6. Landing wheels.

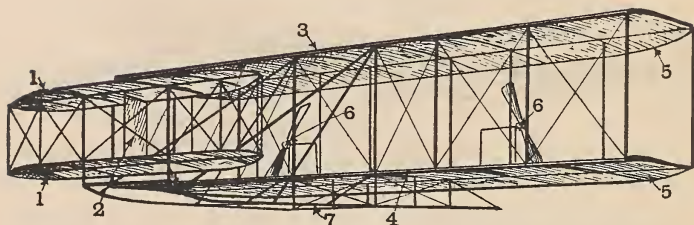
(3) THE HOWARD WRIGHT BIPLANE.



1. Biplane dampers. 2. Upper main plane. 3. Lower main plane. 4. Ailerons for lateral stability in turning. 5 and 6. Upper and lower planes of tail. 7. Vertical planes, forming sides of box tail (rudder in centre). 8. Vertical planes at ends of main planes, to give lateral stability and directional sense. 9. Body for driver and engine. 10. Main landing wheel. 11. Tail wheel. 12. Wing wheels. 13. Twin propellers running in opposite directions on the same shaft.

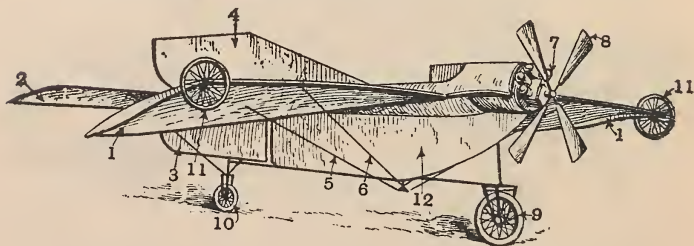
PARTS OF EXISTING MACHINES (Continued).

(4) THE WRIGHT BROS. BIPLANE.



1. Biplane forward dampers for vertical steering. 2. Fixed vertical plane to give directional steadiness. 3. Upper main plane. 4. Lower main plane. 5. Flexible portions at rear of planes (same at opposite ends) which are warped downwards to right the machine when heeling sideways. 6. Propellers. 7. Landing skates. (N.B.—The rudder, not shown, is at the rear between the propellers.)

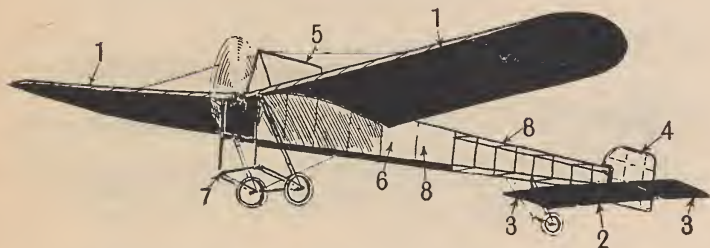
(5) THE ROBERT ESNAULT-PELTERIE (R.E.P.) MONOPLANE.



1. Main planes, or wings. 2. Horizontal tail, which is dipped for vertical steering. 3. Rudder, for horizontal steering. 4. Back fin, to prevent lateral heeling. 5. Rod which warps the back of the wing down to increase the lift. 6. Rod which warps the front down to decrease the lift. (Each wing is so fitted, and when one increases its lift the other wing decreases, so giving lateral control when turning.) 7. Engine. 8. Propeller. 9. Main landing wheel. 10. Tail wheel. 11. Wing-tip wheels. 12. Body in which the driver sits.

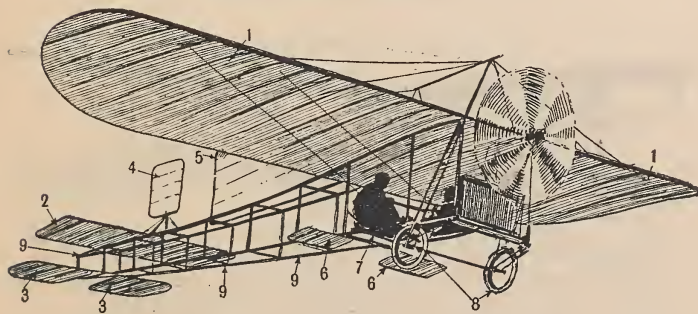
PARTS OF EXISTING MACHINES (Continued).

(6) THE SMALL BLERIOT. TYPE XI. (CROSS-CHANNEL).



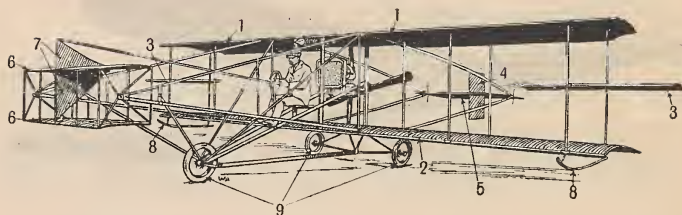
1. Main planes or wings. 2. Fixed tail. 3. Combined aileron and elevators. 4. Rudder, for horizontal steering. 5. Truss, from which the rear edges of the wings are warped. 6. Body in which the driver sits, or naedle. 7. Landing chassis. 8. Fuselage.

(7) BLERIOT MONOPLANE. TYPE XII.



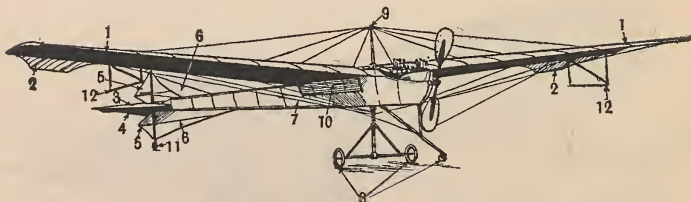
1. Main planes, or wings. 2. Fixed tail (horizontal). 3. Elevators, or tails for vertical steering. 4. Rudder, for horizontal steering. 5. Baek fin, to give stability. 6. Ailerons. 7. Driving seat. 8. Landing chassis. 9. Frame, naedle, or fuselage.

(8) THE CURTISS BIPLANE.



1. Upper main plane. 2. Lower main plane. 3. Ailerons. 4. Fixed vertical tail. 5. Fixed horizontal tail. 6. Biplane elevator. 7. Rudder, for horizontal steering. 8. Skids, to protect wing tips. 9. Landing wheels.

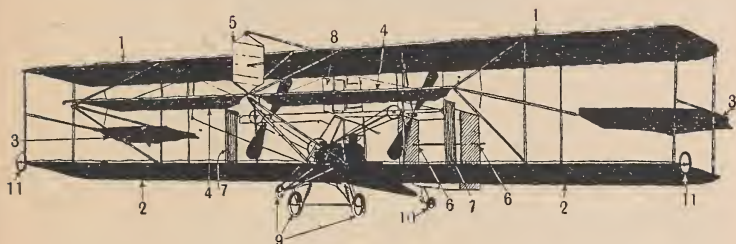
(9) ANTOINETTE MONOPLANE.



1. Main planes, or wings. 2. Ailerons. 3. Fixed tail. 4. Tail for vertical steering, or elevator. 5. Rudders, for horizontal steering. 6. Vertical fins, for stability. 7. Body, nacelle, or fuselage. 8. Landing wheels. 9. King post, to which the wings are stayed. 10. Radiators. 11. Tail skid (sometimes a wheel is used). 12. Supports, to which struts, to protect the wings on landing, may be attached.

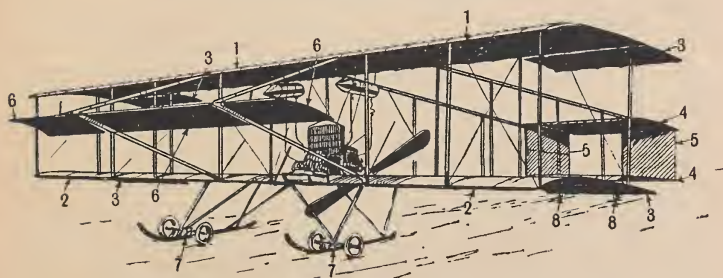
PARTS OF EXISTING MACHINES (Continued).

(10) S. F. CODY'S BIPLANE.



1. Upper main plane. 2. Lower main plane. 3. Ailerons. 4. Elevators, which also act independently as ailerons, or stabilisers. 5. Front rudder, which may be used in conjunction with rear rudders, or may be fixed as a cut-wind only. 6. Rear rudders. 7. Radiators. 8. Tail (sometimes a tail is used, sometimes not). 9. Landing wheels. 10. Spring tail for landing. 11. Wheels, to protect the wing tips.

(11) THE FARMAN BIPLANE.



1. Upper main plane. 2. Lower main plane. 3. Ailerons. 4. Biplane tail. 5. Twin rudders, for horizontal steering. 6. Elevators. 7. Combined wheels for starting and skids for landing. 8. Small tail wheels.

FLYING.

CHAPTER I.

THE SPORT OF THE FUTURE.

WHETHER one regards flying as the most scientific of sports, or the most sporting of sciences, there is no doubt about its being the most fascinating pastime possible at the present day. It appeals equally to the scientist, whether of the Lanchester or of the Maxim type, and to the sportsman who does not mind having a fall, and I might say that if one does break one's neck in the process, it is in a trifle more honourable a cause than in chasing an imported fox or a carted tame deer.

Unfortunately, the average man in the street knows nothing about the why and wherefore of flying, and the greatest of experts know very little more. Therefore I propose, as far as my knowledge carries me, to set forth my views on the subject, gathered, I own it, at secondhand, from those who have written on the subject scientifically, from those who have written from experiments only, and from those who are building aeroplanes on the strength of what they themselves have read, seen, and tried. I am quite prepared to be told that I am absolutely wrong on every point, but as all the leading authorities contradict one another with absolute impartiality on so many points, and when they do agree, arrive at their agreement by different roads, and disagree as to how they got there, I shall be in quite good company. And anyhow, I do not set up to be an authority in any way, I am simply an amateur—in both senses of the word—and am as willing to receive enlightenment as any of my readers. In fact, my position is much about that of a pupil teacher, and I only profess to be a few lessons in front of the class as I go along.

WHY AEROPLANES ?

WHY AEROPLANES ?

First of all, I propose to keep this dissertation entirely to aeroplanes as such. Balloons, in their various manifestations, are quite useful. They are good as observation posts; they help to develop in an aeronaut a sense of distance seen from the bird's-eye view, and they get one used to being high up without losing one's head—though, for the matter of that, anyone with a weak head had better stay on the ground—also in war time, on a practically calm day, it is possible that the military dirigible might be of practical value. Probably in the “next war” they will be used in some numbers and with considerable effect. Therefore England should have enough of them to keep level with foreign countries, pending the development to practicability of “the Army aeroplane.” But as a real flying machine, the balloon is as dead as the four-horse coach which preceded the locomotive. The Zeppelin is probably as fine a balloon as ever will be built, but the last one was destroyed by a capful of wind, and I cannot see why the present one should fare any better. Meantime, the more money foreign countries spend on balloons the better. They will have less to spend on aeroplanes, while we in England are making up our minds what we are going to do about it. The Anglo-Saxon mind is somewhat tortoise-like—it moves slowly.

In the light of more recent knowledge of dirigibles the above views are further confirmed. It was shown conclusively during the Great Aviation Week at Reims that the *Colonel Renard*, the fastest dirigible then existing, could not keep anywhere near her course round a 10 kilometre circuit when there was the slightest breeze. The aeroplanes were doing their 10 kilometre laps in anywhere between 8 and 10 minutes; the *Colonel Renard* took 15 minutes. Also the newer *Zeppelin* dirigibles, the *II.* and *III.*, always seem to get into trouble whenever they go out except in calm weather, and it has been shown that the famous 750 mile voyage of the *Zeppelin II.* from Friedrichshafen to Goppingen was mainly a long drift before the wind,

and only one propeller was used most of the time. However, dirigibles have, at present, the advantage of being able to rise higher than aeroplanes and to carry effective crews and loads of explosives, so for some time to come they must be regarded as military weapons of some considerable importance.

Further, I propose to leave the Helicopters alone, because a helicopter, without supporting planes, is too dangerous to be within the range of practical politics—unless one reverts to the eighteenth century principle of carrying out one's experiments with condemned criminals as aeronauts. If anything goes wrong with the engine the descent is too abrupt. On the other hand, if one uses planes, with helices (or screws) for rising, the planes are going to get in the way of the helices and the helices of the planes, and everything is bound to be inefficient and cumbersome and complicated, unless some genius discovers an absolutely new application of mechanical laws.

More recently I have seen it stated that if the blades of a helicopter be made sufficiently large they will, when the power ceases to act, turn themselves into a series of planes which glide down in a spiral path, and so will descend even more slowly than an aeroplane gliding from the same point in a straight line. This seems quite right in theory, but it must be remembered that the comparison must be between the blades of the said helix and an aeroplane whose planes equal in efficient lifting area the sum of the blades of the helix. Now, if a helicopter were made of such a size as to compare in this way, it seems to me that it would be rather hard to prevent the hull (so to speak) of the machine from spinning round the axis of the helix, if one helix only were used, instead of the helix itself turning; and if two or more helices of such area were used the machine would be an enormous size. However, there is a possibility of something being done with this type of machine where height only is desired, say for military observation purposes, because it has undeniable advantages over the captive balloon, which in utility it seems to me somewhat to resemble. I cannot

yet persuade myself that the type is useful for actual purposes of voyaging from place to place.

After all, nature is generally a safe guide in most things. Taking it all round, the aeroplane is the thing to look to, at any rate in the near future, so let us consider it, and it alone.

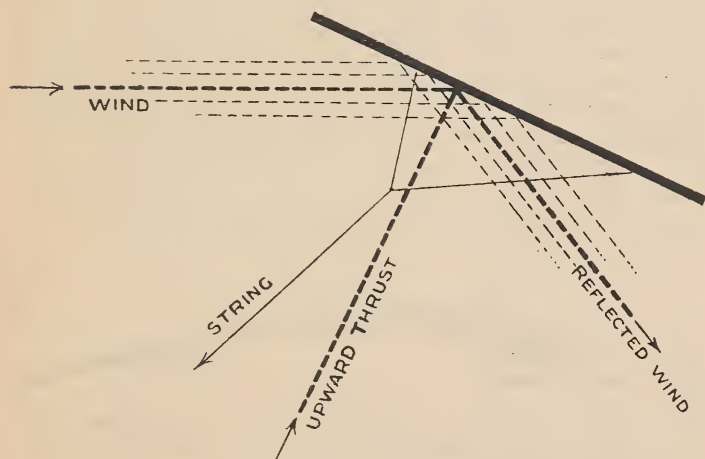
WHY IT LIFTS.

Naturally, the first thing one wants to know is, why does an aeroplane lift at all? A friend of mine compares it to a raft floating on the water, but that strikes me as false analogy, for in that case one is dealing with two elements of different specific gravity, with the raft (of yet a third specific gravity) floating between them. In the case of an aeroplane, the specific gravity of things, as such, does not really enter into the subject at all. The sustaining force in this case is really a question of varying pressures on given surfaces. First of all, I recommend anyone who intends to study the subject to read as many text books as possible, for therein lies much accumulated wisdom, wisdom in what to avoid as much as in what to act upon, but I warn my readers that a course of text books will destroy any blind faith in the experts who compiled them. However, the first thing one learns is that if you take a flat plane and tilt it upwards against a horizontal wind it has a tendency to rise. Everyone who has flown a kite knows this, of course, but even then the kite-flier may not know the exact reason. Put in the simplest way, it amounts to this, that the wind hits the plane on its underneath side and tries to blow it backwards, but if the plane is held so that it cannot move back (as in the case of a kite), and is also held so that the hinder part cannot move above the front, and so bring the front edge below the horizontal, the whole thing is naturally forced upwards somewhat, as shown in the diagram on next page.

The angle of reflection being equal to the angle of incidence (for all practical purposes) in wind as in everything else, the wind striking the plane reflects at the same angle, and the upward thrust is a line bisecting the angle

WHY IT LIFTS. (Continued).

formed by the two. Of course, that is only very roughly how it works, for in reality there are complications caused by the lower strata of wind cutting into the wind of the upper strata reflected from the plane, and so forth, but that is the general principle of the thing. Now, if one builds a big plane, and fits it with an engine, and that engine drives a screw hard enough to push it into the wind with sufficient force, the effect is the same as that of anchoring the plane to the ground and letting the wind push it upwards. The trouble lies in finding the best shape to make the planes,



the best form of engine to give much power at a low weight, the best place to put the engine when you have made it, the best shape and size of screw to use, the best way to steer the plane (both horizontally and vertically) when you have got it in the air, and the best way to keep it from capsizing when you have made it steerable. No one has yet discovered the absolute best of any of these things. When we *have* discovered them we shall have the perfect airship. Meantime, we are improving.

CHAPTER II.

THE BEST FORM OF PLANE.

SO far as the best form (or rather shape) of plane is concerned, I believe we are nearer perfection in this than in anything else about the machine, though in arriving at the shape one finds authorities differing as to the exact action that makes it the best. A series of very interesting experiments was carried out by Mr. Horatio Phillips (a well known member of the Aeronautical Society) as long ago as 1885, which settled once and for all the section of plane which gives the most lifting power for a given area. Sir Hiram Maxim carried out similar experiments some years later, and arrived at a similar result. Mr. José Weiss, another member of the Aeronautical Society, who has made very successful models, arrived at the same conclusion, also by independent methods.

The section, as near as no matter, is thus—



the "hump" reaching its highest point not more than one-third of the distance towards the tail.

Owing to the thickened front of the plane (or aerofoil, if one prefers the more scientific term) the highest point of the curve of the under surface comes naturally somewhat further back than the highest point of the upper surface. Mr. Weiss is convinced that the rear edge of the plane must taper to nothing, so as to give the wind a clean run off and to prevent eddies at the rear. The mere existence of such eddies is proof positive of the fact that power has been exerted in causing them, and therefore the plane which causes the least eddies behind itself is the most efficient.

THE BEST FORM OF PLANE. (Continued).

The experiments took the form of suspending small planes in a current of air of known speed, and measuring the lifting power of various planes of various sections. Phillips produced his current by a steam jet blowing *away* from the plane, which was suspended in a large pipe, so that it was acted upon by an induced draught. Maxim suspended his planes at the outlet of a similar pipe, and blew upon them with a rotary fan, due precautions being taken against any whirling action of the current by placing various grids inside the pipe to keep the current straight. The pipes, in which these, and similar, experiments are made, are known as "wind tunnels," and will become standard equipments in all physical laboratories before long. Phillips's planes were 16in. long \times 5in. wide, whereas Maxim's were 3ft. long \times 12in. wide, roughly an "aspect ratio," as it is called, of 3 to 1 in each case.

In the flying machines of to-day the fashionable size is about 40ft. \times 6ft. 6in., or, roughly, an aspect ratio of 6 to 1.

It may be as well to explain here that the aspect ratio mentioned is that of each individual plane. When speaking of the machine as a whole, the aspect ratio of all the wings together must be taken into account. For example, a biplane having each of its planes 39ft. \times 6ft. 6in. would be practically equivalent in its lifting effect to a monoplane having an overall spread of 78ft. \times 6ft. 6in., and therefore the aspect ratio of the machine as a whole would be 12 to 1. Similarly with a triplane or other multiplane; the true aspect ratio would be ratio of the length of all the planes taken together to the average depth.

Mr. Phillips, whose opinion is, at any rate, worthy of careful consideration, seems to believe that the thing which really counts is the length of "entering edge," *i.e.*, the edge which meets the wind, and that the depth of the actual plane behind it does not matter very much, so long as it is the right shape. The flying machine (steam driven) which Mr. Phillips built about 1890 had a number of long narrow planes arranged in a frame one above the other like a Venetian blind, and it lifted an enormous

weight in proportion to its power, but, of course, at that time Mr. Phillips was handicapped by having only a steam engine, so he was unable to do more than make his machine fly round a circular track, to which it was confined by steel rods connected to a central pivot.

That Mr. Phillips is justified in his belief was proved by M. Blériot at the Reims Aviation Meeting. In his effort to win the prize for the fastest lap of the 10 kilometre track, M. Blériot had about a foot depth of fabric removed from the rear edge of the wings of his No. 22 machine, thus raising his aspect ratio very considerably, though reducing what was generally regarded as his "lifting" surface. As a result the machine carried the same weight and flew very much faster with the same power. This would seem to prove that the depth (or, if one prefers to call it so, the fore and aft width) of a plane acts as a very considerable head resistance if carried beyond a certain depth. Further proof of this theory is provided by the fact that in all soaring birds the wings are very long and very narrow (*i.e.*, they have a high aspect ratio), whereas the flapping birds have short, deep wings with a low aspect ratio.

Sir Hiram Maxim also made a large steam-driven machine, which ran *on* rails at the start and *under* rails when it lifted. This machine had rather "deep" planes, that is to say, the aspect ratio was low, but it also lifted a considerable weight in proportion to its power.

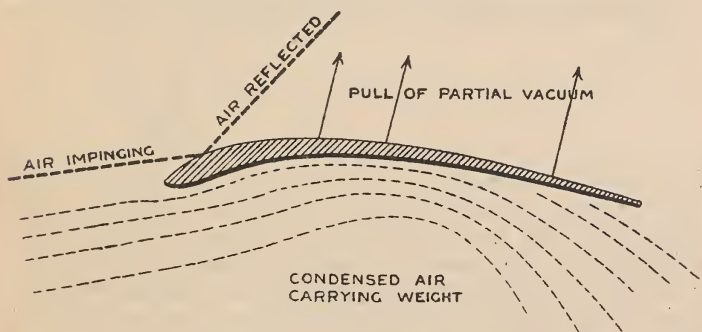
However, to return to the "shape," or rather the vertical section, of the planes, as apart from their aspect ratio—a perfectly flat plane gave a good "lift," but it took too much "thrust," as Phillips calls it; or "drift," which is Maxim's word. I do not like the word "drift," for it implies an actual motion in an undesired direction, whereas thrust implies exactly what it means, either the horizontal thrust of the air against an anchored plane, or the thrust of a moving plane against the air, according to what one is doing with the plane at the time. A lot of other shapes were tried, but the Phillips section always gave the best results, in that it gave a big lift, even when quite horizontal,

THE BEST FORM OF PLANE. (Continued).

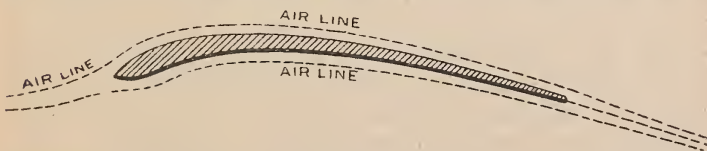
and a very small thrust. Obviously, the further you get your plane from the horizontal, for any given weight lifted—or speed of lift—the greater will be the horizontal thrust; so the greater the lift in proportion to the thrust, the better the plane for efficiency. This type of plane will give quite a good lift when perfectly horizontal, but its most efficient angle is between 1 in 14 and 1 in 16 up from the horizontal line of the wind. Now where the authorities differ is in just why this plane lifts so well.

THE DIFFERING REASONS.

Phillips says the wind strikes the nose of the plane and reflects upwards, thus causing a vacuum, or rather a partial vacuum, on the top, and so holding the plane up in the air—or causing it to be sucked up, if you prefer it so. The air striking under the front forces the whole plane up, and is assisted by the vacuum on the top thus—



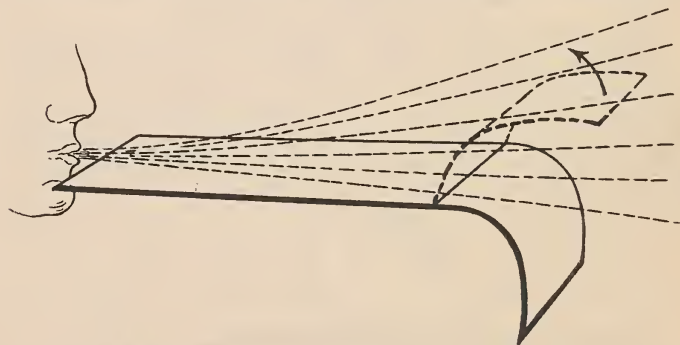
Sir Hiram says the air follows exactly the surface of the top and bottom of the plane, and behaves thus—



He says that the air leaving the tail of the plane at an angle which is the resultant (or average, if you like it put

THE DIFFERING REASONS. (Continued).

so) of the angles of the top and bottom surfaces of the plane buoys the plane up. Mr. José Weiss showed me a very simple little experiment which seems to disprove Maxim's theory. Take a sheet of paper, say, 6in. long and about 4in. wide. Fold it crosswise 2in., or slightly less, from the end, thus leaving a flat surface 4in. square, with a flap at one edge 4in. long and 2in. wide. Now bend the fold backwards and forwards till it becomes limber, like a hinge. Next curve the flap till the whole thing is about this shape—



Now hold the edge of the paper close to the chin and blow along the top of the paper, so that none of the draught goes under the flat paper, but all along the top. You will find that the curved flap will rise and stand upright, as shown in the dotted curve on the sketch, and will hold quite steady there as long as you go on blowing. On the other hand, if you place the flat part *over* your lips, and blow along underneath, the flap will rise simply because of the pressure against it, and it will keep on rising and falling back on to the draught, nor in any case will it rise to the same height as it will when blown at from above. Mr. Weiss had tried this experiment on a big scale with a rotary blower blowing along a table and a metal curved plane hinged to the edge of the table; in the curve of the metal plane he soldered a little hook, and from this hook he was able to suspend 6 ozs. of weight, though the plane used was only a few inches each way.

THE DIFFERING REASONS. (*Continued*).

He also passed smoke through the blower, and found that it rose all the time after hitting the plane, instead of following the curve of the top and shooting downwards. That simple experiment seems to prove fairly conclusively that Phillips, supported by Weiss, are right in their vacuum theory, and that Maxim is wrong.

FURTHER CONCERNING THE VACUUM THEORY.

A further proof of the vacuum theory has since been given me by Mr. Harold Piffard, who has done a great deal of experimenting with power-driven models, some of them of considerable size. Mr. Piffard attached to the top surface of his planes a number of thin strips of tissue paper, gumming one end to the plane and leaving the other end free. When travelling at speed through the air he found that those strips at the front of the plane stood up and leaned backwards, much as shown by the dotted line of reflected air in the first of the two figures at the beginning of this section; those in the middle stood upright in the direction marked "pull of partial vacuum"; and those attached to the extreme rear edge of the plane lay flat in a forward direction, showing that the air supply to the partial vacuum on the top of the plane came from the compressed air underneath the plane which curled round the rear edge and rushed forward up the top surface.

This theory would appear to account for two phenomena. The first is the fact that a short section, *i.e.*, a narrow plane, is more efficient than a long one. For if the plane be narrow, this air sucked up behind will meet the reflected air from the front edge before it has time to curl over backwards, and thus the combined current and consequent pull will be upwards and forwards. Otherwise, if the plane be long in section, and the highest part of the curve be not high enough, the reflected current will curl over on to the top of the plane, and the sucked-up current behind will also curl over, and the result will be the destruction of the desired vacuum. The second is the fact that it has been observed scientifically that a properly curved surface has actually, at certain angles for

certain curves of plane, a distinct forward tangential thrust. Or, to put it in simpler language, there is some force (I imagine it to be that of the forward thrust of the compressed air curling round the rear edge of the plane) which acts on such a plane in a forward direction, and, by giving a forward thrust, diminishes the power necessary to propel the plane through the air. It is said that this tangential thrust only exists when the angle of inclination, or angle of attack, of the plane is between 3° and 30° in relation to the line of wind through which it is progressing. This thrust was first observed by the late Professor Otto Lilienthal.

It is also important to notice that the exact and most efficient curve, and height, of the "hump," of a plane varies according to the speed at which the plane has to travel, but, so far as I can gather at present, these dimensions are only to be arrived at by experiment, and have not been, so far, reduced to an exact mathematical formula.

THE CHIEF FORCE.

However, there can be little doubt that the greater part of the actual work of supporting the plane is done by the underneath surface of the plane. This surface meets still air, or rather air travelling at a negative velocity to that at which the plane itself is travelling, and forces that air downwards. That is to say, it overcomes the inertia of that air, and the reaction of the air, in the act of being displaced, is what really supports the weight of the plane. Therefore the weight which the plane is capable of sustaining (including its own weight) depends upon the mass of the air it is able to capture and force downwards in a given time. Thus a small plane travelling very fast, or a big plane travelling comparatively slowly, may, in a given time, capture the same amount of air and deliver it downwards, in which case either would carry the same weight. Just exactly what part the partial vacuum on the top surface plays in this action I do not pretend to understand, but I do know, from other people's experience,

that it has a very important part to play, and that the "humped" plane with the "Phillips entry" is by far the most efficient.

So much then for the section of planes. One could fill pages very easily with descriptions of the various experiments which have been tried by various investigators, but I can in this book only deal with general principles, so we must turn our attention to other aspects of the aeroplane question, such as the surface of the planes and designs of the machines.

CHAPTER III.

SURFACES AND FRICTION

NOW as to surfaces of planes. Sir Hiram Maxim sets little value on what is known as "skin friction," though he was careful to get his surfaces as smooth as possible. Mr. Fred. Lanchester works out with much mathematical ingenuity and intricacy of figures exact calculations for the coefficient of friction at various speeds. However, a number of excellent results have been obtained by rule of thumb, and it seems fairly obvious, as a matter of plain commonsense, that the faster you drive a plane through the air, the more the air in its immediate neighbourhood is compressed and the more "skin friction" there will be. I notice that Mr. Lanchester, in the second of his excellent volumes on Aerial Flight, reckons the air resistance of wire wing-stays and such small parts as skin friction. It seems to me that, logically, he ought to reckon with them the wind resistance of the general framework, driver, engine, and everything else except the actual planes. True, he is only treating of soaring models (under the derivative title of "Aerodonetics"), and so men and engines do not enter into the question, but I am just following his idea to its logical conclusion. Actual "skin friction," I take it, is the resistance offered by a surface to the wind in excess of what a surface would offer if air did not "stick" to it.

Curiously enough, the people who have done the most flying seem to be the people who have paid the least attention to niceties of plane surfaces. Even the exact copy of Wilbur Wright's machine, as shown in Paris, was simply a collection of sticks with a sort of waterproof fabric stretched over them, and the Voisin machines of Farman and Delagrangé were little better, though during 1909 much improvement has been made. The Blériot, Esnault-Pelterie, and Antoinette machines

seem to have been built with some idea of decreasing skin friction, but by far the most carefully built machine in this respect that I have seen so far is the one built by Howard Wright at Battersea. By the way, Howard Wright is no relation to Wilbur or Orville; he is an Englishman. Everything about this machine is made as smooth and "slippery" as possible. To diminish wind resistance, the driver and engine are boxed into a long bird-like body, and this body is covered with a fabric similar to that used in the planes, all this fabric being varnished and smoothed down till there is as little as possible to catch the wind either in the way of wind resistance, as such, or a skin friction pure and simple.

COMMONSENSE DESIGN.

It seems probable to me that neglect of this matter of the construction, surface, and material of their planes is one of the most important of the many reasons why those men who have actually succeeded in flying have had to use such excessive horse-power to do as little as they have done. Commonsense would seem to show, when such independent experimenters as Phillips, Maxim, Weiss, and Lanchester all agree more or less closely on the distinct superiority of the plane with the "humped" front (or "Phillips entry"), much curved on top and less curved on the underside, and when this finding has been endorsed by nature itself in the construction of every soaring bird's wings, that it is sheer waste of power simply to stretch fabric over wooden frames, some curved and some flat, without apparent regard to the shape of the top, or the wind resistance of the wooden slats underneath, besides leaving entirely out of the question the correct design of the under surface of the plane, which design, in the case of most of the French machines, simply does not exist. Another point which seems to have been neglected is that of "aspect ratio." One sees planes of all sorts and sizes, without any attempt at agreement as to the proportion between the "spread" of the planes and their width (or should one say "length"?) fore and aft. Mr. Horatio

Phillips believes that the longer one can get one's "entering edge" the better (*i.e.*, the greater the spread the better), but the fore and aft dimension does not matter, except that it should be as small as possible. That is to say, the ideal plane has infinite spread and infinitesimal depth. However, for practical working purposes an "aspect ratio" of 6 to 1 or 7 to 1 seems to be the most practicable. By "aspect ratio" is meant the ratio of the length of the plane to its width, *i.e.*, if a plane is 39ft. long and 6ft. 6in. wide, it has an "aspect ratio" of 6 to 1. "Aspect" itself may be either "pterygoid" or "apteroid." "Pterygoid aspect" is "in the position of a wing," that is to say, the long edge is across the line of the machine's flight, as in all machines that have flown successfully. "Apteroid aspect" is "with the planes lengthwise," or with the short edge leading. A number of models have been made with the planes in "apteroid aspect," and they have been made to fly simply because of the enormous power exerted for a short while by an elastic-driven propeller. In such cases the machine has really become a projectile, and the planes have acted just as the feathers of an arrow act, having given the machine directional control, but they have not actually supported it in the air. That is to say, if the power were cut off suddenly the machine would drop to earth (probably stern foremost, pulled by the weight of its propeller), instead of gliding quietly to earth as would be the case with a correctly designed flying machine. The terms "pterygoid" and "apteroid" were coined by Mr. Lanchester, and they will, I believe, become the orthodox terms for the aspects of the planes.

AS TO SKIN FRICTION.

Perhaps, however, before going further into the matter of the shape of planes, I may be permitted to digress a little on the subject of skin friction, and explain more definitely what it is. It is a force acting on any body travelling through a fluid which tends to delay the progress of that body, in addition to the delay caused by direct resistance, and it depends partly on the density of the

fluid and partly on its viscosity or "stickiness." For example, water, heavy lubricating oil, and treacle are all of about the same density, but anyone knows that water is not particularly viscous, whereas treacle is very much so. Now, if you take a tableknife, and draw the blade edgewise and vertically through water you feel no resistance to speak of. If, on the other hand, you draw it in the same way through treacle, you feel a very distinct resistance. Now that is not resistance, properly speaking, for the treacle offers no resistance to the knife edge. It is simply that the blade has become "wet" with treacle, and other molecules of treacle stick to the layer which has stuck to the blade, and so on till you have a distinct viscous drag against you as you draw the blade along. That drag is skin friction. Now, of course, air is nothing like so dense as water; the proportion of density is, I believe, something like 800 to 1, but air is much more viscous than water in proportion to its density, consequently the skin friction on a big plane is something very considerable. In one respect it is well that it is so, for skin friction has a very useful damping effect in the steering of a plane. Consider for a moment what would happen if air were frictionless:—An aeroplane is progressing in a straight line in a frictionless atmosphere. A resistance is set up in one wing, say a piece of fabric splits and stands up on end, or the rudder is jammed over too suddenly. Instantly the whole thing swings round and progresses backwards like a car having a side-slip. Of course, a fall would be the result, as flying machines are not made to fly backwards. But what really happens is that the wing which is brought round by the resistance, that is to say, the outer wing, immediately experiences excessive skin friction (Mr. Lanchester proves that skin friction increases as the square of the velocity, *i.e.*, if you double the speed you quadruple the friction), which is sufficient to calm its enthusiasm and induce it to come round slowly.

DR. ZAHM'S EXPERIMENTS IN SKIN FRICTION.

"Flying" has had the good fortune to merit the approbation and interest of Professor Octave Chanute, the

world-famous American authority on aeronautic science. It was from Professor Chanute that the Wright Brothers received their early education in the theory of the science which they have done so much to advance in practice, and with his assistance they carried out many of their early gliding experiments. Further, to Professor Chanute was due the practical demonstration of the multiplane glider, long before there existed an engine light enough to drive a flying machine. I am therefore the more honoured that he should take the trouble, as he has done, to indicate certain points in this book which would be the better for elaboration. This subject of skin friction is the first point to which he has referred, and at his request his friend Dr. Albert F. Zahm, Ph.D., of Washington, has sent me a copy of his paper on "Atmospheric Friction," which was communicated to the International Aeronautic Congress of 1904. I wish, herewith, to acknowledge the kindness of Dr. Zahm and to thank him for the enlightenment received from the work referred to. Dr. Zahm had, prior to the compilation of this paper in 1904, carried out a number of elaborate, exhaustive, and delicate experiments in order to measure as accurately as possible the effect of air friction on planes. To quote Dr. Zahm, "It has long been known to marine science that in a well formed vessel one of the chief elements of resistance is the skin friction of water on its sides; and by analogy it was surmised that a fair-shaped body in the air might be retarded in a similar way by the tangential drag of that fluid. The present research seems to prove that the frictional resistance is at least as great for air as for water, in proportion to their densities. In other words, it amounts to a decided obstacle in high speed transportation. In aeronautics it is one of the chief elements of resistance, both to hull-shaped bodies and to aero surfaces gliding at efficient angles of flight." Dr. Zahm's experiments were carried out in a "wind tunnel," similar to that employed by Mr. Horatio Phillips and Sir Hiram Maxim in their experiments with planes, only, in the case of Dr. Zahm's tunnel, the current was produced by a 5ft. exhaust fan

at one end and a cheese-cloth screen or two at the entrance to straighten the current of inflowing air. The plane itself (which was covered with paper) was 16ft. long, 4ft. wide, and 4in. thick, and was suspended inside the tunnel by wires. It was so constructed that, when the wooden frame, on which it was built, warped at all, it could be trued up flat with scarcely a shade of an unevenness anywhere. The swing of the plane on its suspending wires gave the necessary data for measurements of the pull. To guard against end pressure on the thickness of the plane, the ends were protected by wind-shields, which were connected by a large pipe so that the slight vacuum behind the forward one might be made up for by the extra pressure inside the other, which would be transmitted along the pipe. From these experiments certain very definite results were obtained by varying the wind speeds. These results were further checked by further experiments with varnished boards 25.5in. deep and 1in. thick. The length of board was varied while the wind speed was kept constant. In this case the wind-shields were done away with and the board was given a long, sharp entry and run-off aft, which would minimise head resistance and would not affect skin friction to any appreciable extent in a long length. As the result of a series of these experiments a long table of values was acquired, of which the following are those values immediately affecting the present-day conditions of flying machines. (See following page).

First of all it will be noticed that skin friction does not increase fully as the square of the velocity; and secondly, it will be noticed that the force absorbed in this way is very appreciable. For example, if one takes the main planes of a biplane 40ft. \times 6ft. at a speed of 40 miles per hour, it will be seen from the table that for a 6ft. plane (*i.e.*, half-way between 4ft. and 8ft.) the friction is approximately 0.0130 per square foot. Now the area of the planes is 40ft. \times 6ft. = 240 square feet. There are two surfaces to each plane = 480 square feet, and two planes = 960 square feet of friction surface. $960 \times .013 = 12.48$; or, in other words, there is a dead drawbar pull of $12\frac{1}{2}$ lbs. against

AS TO SKIN FRICTION. (Continued).

the propeller due to skin friction on the main planes alone, without taking in head resistance of any kind, or the friction on ailerons, tail planes, and other frictionable parts, and assuming the planes to have really smooth surfaces not spoiled by unevennesses or cross struts of any kind. Dr. Zahm states that "the frictional resistance of a plane or arched surface soaring at small angles on a horizontal course equals the horizontal projection of the surface multiplied by the average unit friction as given by Table IV." (that quoted above), so that these calculations may be admitted as being fairly accurate.

Further, there is the consideration of the longitudinal frame members, which is the reason for my including the 32ft. plane in my quotation of his table. 32ft. is a fair length for the four main fore and aft frame members of

FRICTION PER SQUARE FOOT FOR VARIOUS SPEEDS AND LENGTHS OF SURFACE.

(N.B.—"Length of surface" implies the length from front to back in the direction of the wind stream.)

Wind speed in miles per hour.	Average friction in lbs. per square foot.					
	1ft. plane.	2ft. plane.	4ft. plane.	8ft. plane.	16ft. plane.	32ft. plane.
20	0.00402	0.00384	0.00365	0.00349	0.00332	0.00317
25	0.00602	0.00579	0.00551	0.00527	0.00501	0.00478
30	0.00850	0.00810	0.00772	0.00736	0.00701	0.00668
35	0.01130	0.0108	0.0103	0.0098	0.00932	0.00888
40	0.0145	0.0138	0.0132	0.0125	0.0125	0.0114
50	0.0219	0.0209	0.0199	0.0190	0.0181	0.0172
60	0.0307	0.0293	0.0279	0.0265	0.0253	0.0242
70	0.0407	0.0390	0.0370	0.0353	0.0337	0.321
80	0.0522	0.0500	0.474	0.0452	0.0431	0.0411
90	0.0650	0.0621	0.0590	0.0563	0.0536	0.0511
100	0.0792	0.0755	0.0719	0.0635	0.0652	0.0622

a Voisin or Farman machine. Each of these would have a circumference of perhaps 8in. (*i.e.*, 2in. square) or two-thirds of a foot, which would give an area of nearly 22 square feet each. There are four of them, giving 88 square feet in all, so at 40 miles an hour the resistance from skin friction alone would be 1.144 lbs., without allowing anything for pure head resistance.

These rough calculations give one some idea of how the power on a fast machine is swallowed wholesale by all kinds of resistance which one is apt to disregard, simply because one has been living all one's life in air and has come to regard it as an impalpable medium which offers very little resistance.

The solidity of air was well brought home to me when at Reims recently. I happened to be standing with some friends in a direct line exactly 55 yards behind Curtiss's machine, which won the Gordon Bennett Cup, when he was tuning up his engine. Curtiss had a big powerful engine and apparently a very efficient propeller. When he started up his engine the propeller jumped into its full speed inside two seconds, yet for a full ten seconds we did not feel a breath of wind. We could see dust and scraps of paper being caught up off the ground and whirled round by the reflected whirls, but disturbance in the main mass of air travelled very slowly. When the current from the propeller had overcome the inertia of the surrounding air, and had reached us, it blew a full gale, for the propeller was shifting the air at the machine's flying speed of about 45 miles an hour. Suddenly Curtiss switched off his engine and the propeller stopped instantly. Yet for another seven or eight seconds the gale continued to blow. Such is the solidity of the medium in which we live, and such is the momentum which can be imparted to it.

However, this is getting away from Dr. Zahm and skin friction. On the subject of quality of surfaces and the variations due thereto, Dr. Zahm has some interesting remarks to make: "Some measurements were made with the 4ft. friction board covered with various materials to observe the effect of quality of surface upon the

tangential resistance. Practically the same friction was observed whether the board was covered with dry varnish, or wet sticky varnish, or sprinkled with water, or covered with calendered or uncalendered paper, or glazed cambric, or sheet zinc, or old English drawing paper, which feels rough to the touch. But when the plane was covered with coarse buckram having sixteen meshes to the inch, the friction at 10ft. per second was ten to fifteen per cent. greater than for the uncovered surface, and the friction increased as the velocity rose to the power 2.05, or approximately as the square of the speed.

"The fact that such a variety of materials exhibit practically the same friction seems to indicate that this is a shearing force between the swiftly gliding air and the comparatively stationary film adhering to the surface or embedded in its pores. If, as seems to be true, there is much slipping, this means that the internal resistance of the air is less at the surface than at a sensible distance away. As the shearing strength of a gas is due to the interlacing of its molecules owing to their rapid motion normal to the shearing plane, it may be that the diminution of shear near a boundary surface is due to the dampening within the film of the component of molecular translation normal to the surface." This takes some thinking out, but it is worth the trouble involved.

Mr. A. P. Thurston, B.Sc. of London University, a rising young scientist, who has had much to do with the making of Sir Hiram Maxim's machines, ascribes these phenomena, usually attributed to air friction, to a manifestation of force which is known as "kinematic dispersion." Roughly stated, the operation of this force is as follows: Air friction as such would presuppose that any one molecule of air, on coming in contact with a body, would slide, or scratch, along it, keeping in contact with it all the time, whereas in the case of kinematic dispersion the operation is analogous to the effect of an elastic or resilient body hitting another and bounding off it, which is the supposed action of the molecules of air. As Mr. Thurston puts it, if one can imagine a railway train running along and

being pelted all the time with heavy balls which hit it and bounce off again, one can easily realise that the impact of these balls, and the exertion of the force necessary to repulse them, and at the same time to give them an impulse in a forward direction, would in time slow the speed of the train. So in the case of a body travelling through the air. It is being continually pelted with molecules of air, and the more acute the opposing angle at which they encounter the body the more they retard it. The idea is ingenious, but for practical purposes it matters little whether air friction is pure friction as such, or the shearing of gases (as mentioned by Dr. Zahm), or the pelting action of molecules (as believed by Mr. Thurston), the observed results of its resistance to progress are the same, and calculations can be made accordingly.

CHAPTER IV.

MATHEMATICS *v.* PRACTICE.

BY the way, real study of aeronautics is so involved and hampered by the vagaries of mathematicians that I cannot help being reminded of the story of Stonewall Jackson in the American Civil War. Stonewall Jackson was one of the few generals of the day who had a real staff of trained engineers, and he was immensely proud of them. It so happened one day that he wanted to get his army across a pretty considerable river ("crick" is the American, I believe), so he instructed his chief engineer to prepare plans for a bridge for horse, foot, and artillery as quickly as possible. Then he sent for the chief carpenter of his Army Transport Corps (or whatever did duty for it), and told him to get together materials for a bridge, for which the engineering department would in due course furnish drawings. At the end of a day and a half the chief carpenter went up to Jackson and said, "General! I guess that bridge is finished, and the army can get right along; but we're still waiting for them picturs." Our position seems something like that. I have the greatest respect for mathematicians (the more so because I do not understand their mathematics), and one can learn quite a lot of really useful facts and points of design from them; but in the meantime a considerable number of persons are flying very practically, and we are "still waiting for them picturs" of what a flying machine ought to be.

THE SHAPE OF PLANES.

In the earlier chapters we have already seen that the right *section* of plane is that with a hump at the front edge. Now, when one gets on to the shape of the planes, one reaches a subject which has not really been decided, and is not likely to be decided for a good many years to come. Lanchester proves mathematically, and fairly

THE SHAPE OF PLANES. (Continued).

clearly without mathematics, that a loaded aeroplane must be of rectangular plan, because the straight edges at each end of the "spread" tend to keep it stable (or steady) sideways. He believes that the curved front line of a bird's wings, when spread out and viewed in plan, is merely an anatomical accident. Phillips, on the other hand, says nothing about the shape of the ends of his planes. The leading edge is the only thing which concerns him. Weiss, again, makes the front edge of his models curved like the edge of a bird's wing, and tapered off at the ends in just the same way as a bird's wings taper off. The Farman, Wright, and Voisin machines have straight leading edges and rectangular plans. The Antoinette, Blériot, and Esnault-Pelterie monoplanes have a very decided taper from the body to the wing tips. So we have no dependable dictum as to what is the right design in shapes.

When we come to the disposition of the planes there are even more widely divergent views. Phillips disposes his long narrow planes one above the other like the slats of a Venetian blind. He gets an enormous lifting effect, but I believe he has never attempted a free flight. The Wrights, Voisins, Farman, and others, such as Howard Wright and Pischoff and Koechlin, make their machines into biplanes, *i.e.*, double-deck machines, with one plane above the other, and the machinery fitted on top of the lower plane, the chief reason being, I believe, to get plenty of "entering edge," and at the same time to avoid having an unduly wide "spread." That seems reasonable enough, but all these "superposed plane" machines seem to me to be lacking in efficiency. At any rate, they do not strike the eye as having the same chance of efficiency as a monoplane with a body like a bird's underneath the supporting surfaces. Necessarily the monoplanes have less spread, or at any rate if they have the same spread they have only one "deck" of it, which means that they have less supporting surface. This question of supporting surface brings us to an extremely complicated phase of the question, which no one seems to have solved satisfactorily as yet. Obviously, if you have a very big supporting surface, as in the biplanes,

THE SHAPE OF PLANES. (Continued).

you will be able to lift at a lower speed than you would lift a machine of the same weight with smaller wings, for you will get a lift of so many pounds to the square foot of surface at a given speed, and the more square feet you have the bigger lift you get. Equally obviously, if you have a smaller number of square feet of lifting surface, you must drive your machine correspondingly quicker to get the extra number of pounds per square foot to make the total number of pounds pressure necessary to lift the whole equipage.

“AIR SPEED” AND “LAND SPEED.”

By the way, as we are discussing speeds, it would be as well to note here that when one speaks of “miles per hour” in aeronautics, one does so without any reference to the speed at which one covers the ground. It is purely a matter of speed with relation to the surrounding air, for recollect as soon as one quits the ground one depends absolutely on one’s speed in proportion to the surrounding air for one’s support. Suppose, for example, an aeroplane would lift at a speed of 30 miles an hour. Now, if a 30 mile an hour wind were blowing (it would be approximately a full gale), and the machine were brought out and simply held up against it, it would rise like a kite. If a 40 mile an hour wind were blowing, and the engine were to drive the machine at 30 miles an hour into it, the machine would rise and soar, but it would do a steady 10 miles an hour backwards, so far as the earth surface was concerned, although it was doing a steady 30 into the wind. It is just the same with a boat. If you put a 6 knot boat into a 10 knot current it does 4 knots sternwise so long as it heads up stream. If you turn it round it does 16 knots down stream. Similarly, if you turn your 30 mile an hour aeroplane round with a 30 mile an hour wind behind it, it promptly does 60 miles an hour down wind. It cannot go any slower, for if it does it loses its necessary 30 mile an hour lifting speed *in excess* of the wind speed, and simply drops. Consequently, one must stay on land whenever the wind speed exceeds the best speed of one’s aeroplane, for if one starts facing the wind one is simply

blown backwards, and if one turns one goes too fast, and in any case one could scarcely start with the wind in one's back; for suppose it were only a 20 mile an hour wind, and the machine needed 30 an hour to lift it, one would have to do 50 miles an hour over the ground in order to catch up the 20 mile an hour wind and do 30 miles an hour *in excess of it* to allow the machine to lift, which would, I fancy, be unpleasant on the average *champ d'aviation*, which usually consists of a grass surface over which a car can hardly travel at all. Of course, as the "land speed" begins to exceed the speed of the air, the machine will begin to lift itself, and so it will grow lighter and lighter as the speed rises, and will "bump" less heavily over surface obstructions, but still a speed of anything over about 30 miles an hour will be decidedly uncomfortable for the driver and risky for the fabric of the machine.

However, if one wished to travel with the wind it would be quite possible to start up against the wind, and then turn down wind with it, making much leeway in the process of turning. But this would be a decidedly risky proceeding, and I believe Mr. Lanchester to be quite reasonably, as well as mathematically, correct when he states that, to be safe, a machine must have a velocity equal to at least twice the speed of the wind it may encounter, so that it may always have a forward speed at least equal to the speed of the wind in the opposite direction. I shall refer to this point later on when discussing the question of stability.

The thing to remember in talking of flying speeds is that no matter what the direction (against, with, or across the wind) the wind pressure on the driver's face is always the same for a given speed, though his speed in relation to the ground may vary between any possible speeds, say between going backwards, standing still over a given point, or doing 60 miles an hour or more.

It is more or less like a man walking on the deck of a ship. If the ship is doing 10 miles an hour in relation to the land alongside, and the man is walking at 3 miles an hour, when he walks towards the bow of the ship he

"AIR SPEED" AND "LAND SPEED." (Continued).

passes objects on shore at 13 miles an hour. When he walks across the deck he passes the same objects at 10 miles an hour, broadside on ; and when he walks from bow to stern he passes them at 7 miles an hour, backwards. The particular mass of wind in which an aeroplane is travelling has its own travelling pace, and so acts towards the aeroplane much as the deck of the ship acts towards the man who is walking on it. The machine may travel how or where it likes in the wind, but the speed of the wind always adds to, or subtracts from, its "land speed," although its "air speed" must not fall below that necessary to sustain it in the air.

CHAPTER V.

SPEED AND POWER.

NOW I am told by those who speak authoritatively that every aeroplane has its own critical soaring speed in relation to the wind through which it is passing (speed over the ground has nothing to do with it, as explained in the last chapter), and that the horizontal speed of the machine is confined within comparatively narrow limits. If you try to exceed this speed you do not go any faster, you simply soar higher. Apparently the extra power is all transferred to the lifting component, and none is expended in horizontal flight, or at any rate very little of it is. The same thing seems to apply to birds; for if you watch a crow trying to make headway against a wind which is too much for him, you will notice that he can go up as much as he likes, but he does not progress horizontally, except backwards. You get what is apparently a verification of this fact in the Wright flying machine. Wright never goes up except in calm, or practically calm, weather, so one would imagine that as he became more expert, and had better engines fitted (I hear he had several), he would fly faster. Yet, as a matter of fact, his speed on all his trials is the same, within very narrow limits. All his improved engines allow him to do is to stop in the air longer, because he is not running his engine "all out" all the time, and in consequence the engine will keep on running for a longer time without overheating.

Further confirmation of this was seen at the Great Reims Meeting, where for the first time flying machines of various types were accurately timed over and over again over the same accurately measured distance. The actual times of any one machine varied very little indeed, and when such variations took place any increase in the time was almost always accounted for by the machine

being blown off its course by a side wind, or through the driver going wide at one of the turning pylons, thus increasing the distance travelled and so taking longer to cover the course although travelling at the same speed. Where a notable increase in speed was made it was generally through an actual alteration in the machine itself, as in the case of the No. 22 Blériot, already referred to, when a big strip was taken off the back edge of the main planes, so reducing unnecessary friction, and, at the same time, slightly reducing the lifting surface, so compelling the machine to go faster to sustain its weight.

I take it that all my readers know that practically all aeroplanes of to-day are fitted with a horizontal rudder (generally in front of the main planes), which steers the machine vertically, *i.e.*, makes it go up or down as the driver wishes. Knowing this, one is tempted to ask why it is that, if a machine rises when extra power is turned on instead of going faster, it would not meet the difficulty if the driver simply turned on more power and steered downwards to counteract the rise of the machine? Seemingly it ought to go quicker then. Apparently the answer is, that when the extra power is got to work the machine rises; then the rudder is turned to steer the machine downwards, and the turning of the rudder in a direction contrary to the natural path of the machine creates a resistance which soaks up most of that power, till the power rises so much that the effect of the rudder is overcome, and the machine just goes on rising (or possibly the power might get "over" the machine, and the whole thing turn a forward somersault). Of course, all this time the machine is travelling horizontally at just whatever its critical speed may be. I make no pretence to being a scientist; so I will not attempt to explain this scientifically; all I know is that I have good authority for saying that it is so, and that it will have a very important effect on the future of the aeroplane. Some notes bearing on the subject are given under the heading of "Variation of Pressure Centres" in Chapter VIII.

ALTERING THE FLYING ANGLE.

ALTERING THE FLYING ANGLE.

Every flying machine is built to fly at a certain angle in relation to the plane along which the wind is travelling. That is the natural "flying angle" of the machine. The greater the angle the lower the speed at which the machine will lift and the greater the power expended in lifting it. *Per contra*, the less the "flying angle," the greater must be the speed of the machine to keep itself up in the air and the less the power expended purely in lifting. This is fairly obvious if you consider the hypothesis set forth in Chapter II., viz., that the machine is lifted by the reaction of the mass of air captured and propelled downwards in a given time. A plane set at a large angle with a low speed will capture as much air as a plane at a small angle but with a high speed. Therefore a certain amount of variation of speed can be obtained by altering the flying angle of the machine. If this alteration be made before starting, the "land speed" of the machine must be either higher or lower, according as the angle is decreased or increased; but once the machine is in the air, the variations of speed will be comparatively small. Steering downwards with the horizontal rudder (or damper) decreases the flying angle of the plane forming that rudder, and so decreases the average flying angle of all the planes forming the complete machine. The machine, as a whole, is then flying at a smaller angle, and *must* go faster to keep itself in the air. Lifting or depressing the front of the machine by means of the horizontal damper means, necessarily, that the main planes will have their flying angle increased or decreased accordingly, which adds to the effect. In machines such as the Howard Wright or Voisin, which carry tails, a similar effect is produced by the tail-planes, but these are set before starting, and so affect the natural speed of the machine, but not its variable speed. The front damper (as explained above) is the only thing which can be used for that purpose.

In the Antoinette, Blériot, and R.E.P. monoplanes the horizontal tail plane is used for vertical steering, and so it affects the speed to some extent, but not in the same way,

ALTERING THE FLYING ANGLE. (Continued).

because lowering that tail plane lifts the tail and increases resistance (or thrust) at the same time that it is decreasing the angle and increasing the speed of the main planes. Consequently it would seem that the variations of speed would hardly be as great in such cases as in machines wherein the vertical steering is done from the front.

HOW POWER IS EXPENDED.

Professor Chanute, when writing me with reference to this book, very kindly suggested that in a second edition it would be well to devote some attention to the relation between the area of surface and the weight carried, as instanced by the fact that the Wright machine carries only 2 to $2\frac{1}{2}$ lbs. per square foot of lifting surface, whereas Blériot carries about 5 lbs. per square foot; also as to the relation of weight carried to the horse-power necessary to sustain it, Blériot carrying only about 27 lbs. per horse-power against the Wright's 40 lbs. per horse-power.

So far as I can see the two questions are mutually interdependent. Taking the first part first, the Wright machine is, in its present form at any rate, a slow-flying machine. As stated earlier in this book, in order to sustain any given weight in the air a machine must capture and force downward a sufficient quantity of air to give a reaction strong enough to sustain that weight. The slower the machine flies, therefore, the greater must be its wing area, or rather sustaining surface area, to capture that amount of air. Consequently the lower the speed and the greater the area, the less will be the pressure per square foot on that area. If the area be reduced and the weight carried remain constant, the machine must fly faster to obtain the necessary pressure to lift that weight, or, in other words, to capture and force down sufficient air to sustain the weight. In this way the greater the weight carried, the faster the machine must fly to keep it in the air, and incidentally, the greater the pressure per square foot on the sustaining surface. Now, taking the two cases in point, the Blériot machine has a wing area of probably less than half that of the Wright machine.

consequently it must have a sustaining pressure per square foot of more than double the pressure on the Wright machine, supposing the weights to be equal. As a matter of fact the Blériot machine itself is very much lighter than the Wright, but the engine is not so very much lighter, and the driver is probably much about the same weight in any case. Consequently the total weight of the Blériot approaches the total weight of the Wright, and consequently the sustaining pressure must be double, or approximately double, that of the Wright.

In order to obtain this pressure, it is obvious that the machine must fly faster, which brings us to the second part of the question, *i.e.*, why Blériot only carries 27 lbs. per horse-power against Wright's 40 lbs. per horse-power. One must assume these figures as approximately correct for the sake of argument, though as scientific figures they would be inadmissible, because, so far as I can discover, no accurately measured brake test of either engine has yet been published. However, assuming them to be near enough, one notes that the Blériot machine is much the faster (as stated above). Now, the power necessary to obtain greater speed in a flying machine, as in everything else, increases much more rapidly than does the speed. Resistance increases as the square of the velocity. That is to say that double the speed means four times the resistance. This is absolutely true of all head resistances, it is almost true of skin friction (*vide* Dr. Zahm's experiments), and it is, I believe, somewhere in the region of truth for the resistance of the planes themselves. Consequently, in order to obtain the extra speed which will give the necessary extra pressure on the planes, the Blériot machine must absorb very much more horse-power for the weight carried than the Wright or any other slower flying machine. In other words, the weight carried per horse-power is less on the faster machine.

In an exhaustive series of experiments, Mr. Patrick Y. Alexander, who has devoted his life and fortune to the cause of aeronautics in this country, has proved conclusively that a large slow-running propeller is much more

efficient than a small high-speed one. Now a propeller is only two or more planes gliding in a helical (or "corkscrew") path, and these planes are governed by much the same laws as the planes of a flying machine. Therefore Blériot, who uses a small high-speed propeller, is losing still more efficiency as compared with the Wrights, who use two large slow-running propellers. Consequently his weight per horse-power is still further reduced.

There are so many independent causes of loss of power in all flying machines to-day that I do not believe it possible to calculate with accuracy in figures just why one machine carries so many pounds per horse-power more than another at any given speeds, but the foregoing notes may perhaps explain, on general principles, how it is that any two known machines carry different weights per unit of sustaining area and different weights per horse-power.

FUTURE POSSIBILITIES.

I imagine there are quite a lot of people who believe that it is only necessary to make a manageable aeroplane, and make it strong enough, and that after that the speed is only limited by the amount of power one can put into it. As a matter of fact, speed depends on a number of other things besides mere power. Chiefly it depends on wing area (or to be more accurate, I should say wing spread), and I believe the future will prove me right when I say that the flying machine of the future must have a variable spread if it is to have a very variable speed. As I have already pointed out, the monoplanes, with a comparatively small spread, have to travel faster to keep themselves in the air, and naturally require more power to do it. It seems natural, therefore, that a machine should be made, ultimately, with a variable spread, so that it will lift at a comparatively low speed, and then when it is at a considerable height reduce its wing area, open up its engine, and get going at a really respectable speed, so that it can be comparatively independent of high winds. The problem of how to design a variable wing will be one of the earliest tasks before the makers

of flying machines, and it promises to be a very difficult one. Incidentally, I should like to hazard the opinion, in support of other speculators on the subject of flying, that once we have become reasonably expert and our machines have become reasonably stable (through correct design) and reasonably free from breakages (engine stoppages do not matter so much), we shall by choice fly at an altitude of a thousand feet or so, where we shall be comparatively free from odd air currents and cross gusts, caused by obstructions or irregularities on the earth's surface, and will have plenty of room to manœuvre in case of temporary derangements of gear—gear in the nautical sense, not in the automobile sense. One may imagine that those who first ventured on the sea in boats kept as near land as possible, but as soon as ships became stable in the water, and fairly stormproof, the first thing the navigators learned was that they were safer well away from the shore than close to it. Another advantage of flying high is that in case of an engine stoppage the aeronaut will have time to look round and choose a landing place. The statement has, I believe, been made that at a height of one mile an aeronaut would be able to take his choice of landing places within a circle of twelve miles radius. He would need a better gliding machine than anything at present existing if he were to do that, for a drop of 1 in 12 means an angle of 4.78° , which is considerably closer to the horizontal than we can manage at present. If the circle mentioned had been twelve miles diameter it would have been nearer the mark, for 1 in 6 is an angle of 9.6° , or much nearer our capabilities. For a descent of this sort a variable spread would be of the greatest possible advantage, for if anything went wrong with the engine when flying high at a big speed with contracted wings, the wings would be at once extended to their full spread, with the result that, though the angle of descent would remain the same, the speed of descent would be much slower and more time would be allowable for choice of a landing place.

In support of this theory of variable spread one may observe the common swift hawking for flies. The swift

FUTURE POSSIBILITIES. (Continued).

is primarily a soaring bird and flaps its wings very little. Notice a swift soaring and then see it suddenly shoot down to pick up a fly. It does not flap its wings, it just lays them along its sides, only leaving the necessary amount for the support needed at the moment, and drops on to its prey with its weight driving it along on a very small spread at a very high speed. Then it opens its wings and its own momentum shoots it up in the air for a considerable distance. After which it soars up on an upward current or, if necessary, flaps its way up to the desired height and place for its next operation. However, that is all a matter for the future, though it is really intimately concerned with the first principles of flying, for one can scarcely claim to have mastered the first principles when one has only acquired the ability to rise from the ground and stay in the air at what is practically one fixed horizontal speed which is rather less elastic than the legal limit for cars.

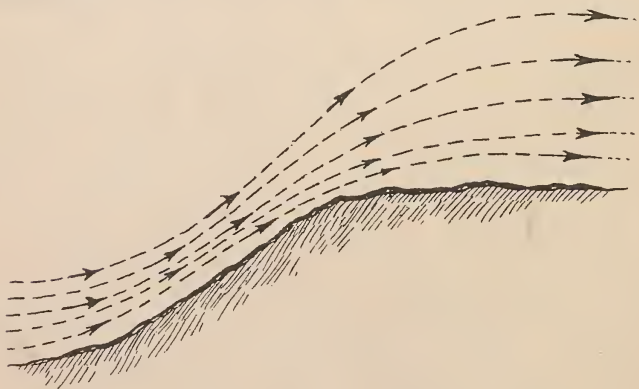
CHAPTER VI.

AIR CURRENTS.

IN the last chapter I mentioned the case of a bird being carried up on an upward current of air, and this seems the right place to dissertate to some extent on the question of air currents. It is a very big subject, and so far as I can gather from exhausting, if not exhaustive, researches, nobody knows very much about it. Even Mr. Lanchester, after minute calculations as to the effects of air on "aerofoils," "stream-line bodies," and the like, has to admit that "the turbulent component of wind motion is a matter of great complexity, at present but little understood; in all probability a wind of any considerable velocity consists very largely of vortex motion, and an aerodone (*i.e.*, a soaring machine), in passing from one part of such a 'vortex pack' into another part, experiences many and varied changes, both as to velocity and direction. . . . Thus the variations are not confined to horizontal fluctuations, but include vertical components of motion distributed in an irregular manner." Where F. W. Lanchester confesses to ignorance, who am I that I should assume knowledge? However, leaving out such interesting details as "turbulent components," "vortices," and so forth, one may assume that wind may be either horizontal (in any direction), downward, upward, or anything between horizontal and the other two directions, which gives the flying machine quite a variety of choice, so to speak. Now, at the present day, no one flies boldly enough to have proved on his own person just the effect of really violent currents at odd angles, for not only Wright, but practically all other fliers, only go up on a calm, or nearly calm, day. No doubt when the machines improve, so that there is less power wasted in merely pushing them along, and a consequently greater reserve is left for adverse circumstances, and when they

AIR CURRENTS. (*Continued*).

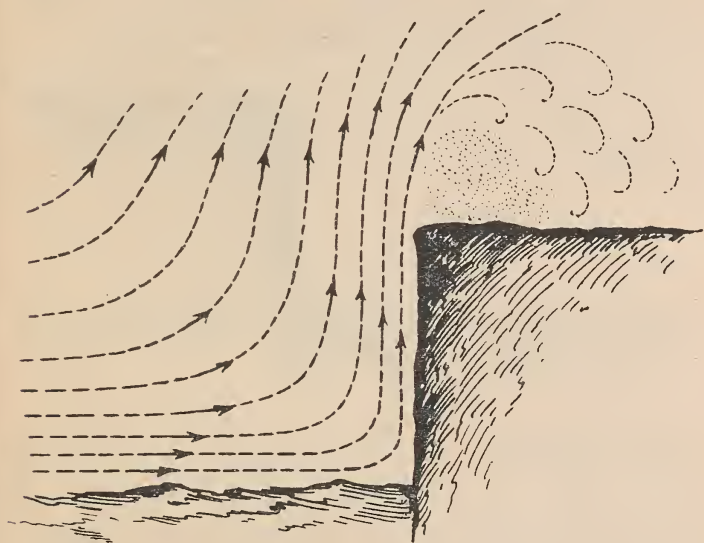
have a greater degree of automatic stability through being properly designed, the various aeronauts will tackle the effects of various currents, and we shall learn more about their behaviour. At present what we do know we know only from experiments with gliding models whose sole propelling power is their own weight. Mr. José Weiss seems to have investigated this question more thoroughly than anyone else I have come across, and his models certainly glide at an angle closer to the horizontal than those of anyone else I know of. Before going into the effect of these currents on the models, it may be as well to see how the currents themselves arise. An ordinary horizontal, or approximately horizontal, wind everyone knows, sometimes to his bodily discomfort. An upward current may be caused in a variety of ways. The commonest cause is when a horizontal wind meets an obstruction, as, for example, the face of a hill. The effect is somewhat thus—



The wind strikes the face of the hill and follows the contour of the surface to the top, when it rises considerably above the top of the hill. The strata of wind some little way from the actual surface rise more nearly vertically than the strata (or streams) close to the surface, which streams follow the line of the hill quite closely. This is presumably

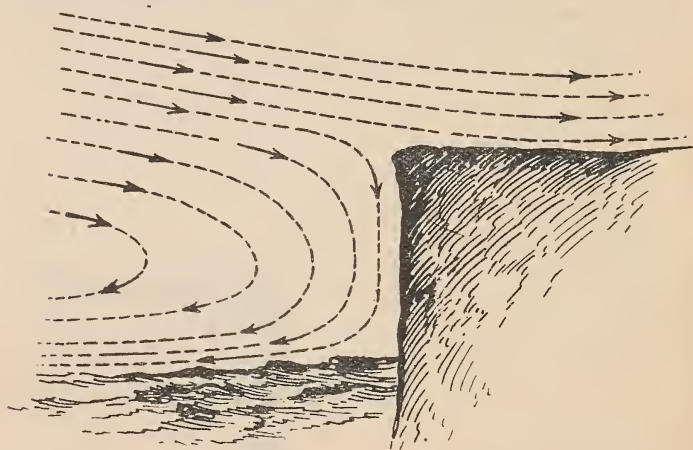
AIR CURRENTS. (*Continued*).

due to the streams next the face of the hill being compressed by the weight of the wind behind as they strike the hill, and then expanding as they clear the top. In the case of wind striking an actual cliff face the effect is more of this nature—



The wind, under considerable pressure, clears the edge of the cliff, and gives rise to what Mr. Lanchester calls a "surface of discontinuity" (indicated by the line next the cliff edge), which shoots upward, much as the wind does from the wind screen of a car. After rising to a certain extent the wind streams curl over in a state of turbulence, giving rise to "vortex packs" and other strange phenomena, and right on the edge of the cliff is a region of comparative calm, or "dead water," indicated by the dotted space. If the wind happens to have a downward tread, as would happen in the case of cold wind from above the sea dropping down *on to* a cliff to replace hot air which is being drawn away owing to the

ascension of still hotter air from some sun-warmed area further inland, exactly the opposite effect will take place, and the effect will be more on these lines—

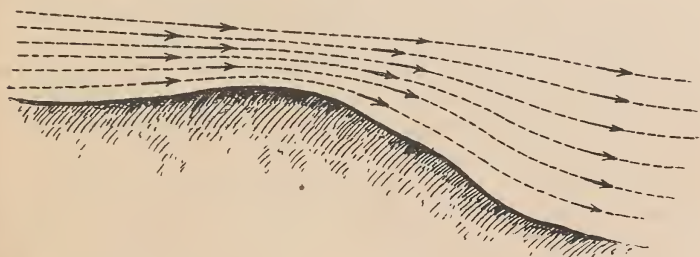


which is the reason why one can stand near the edge of a cliff by the sea on a sunny day and be blown back by a cold wind, whereas on an inland cliff of similar form there would be calm close to the edge and a strong upward wind above it. Of course, it is possible, under favourable circumstances, to get a similar up-draught from a sea cliff, but apparently the neighbourhood of the sea is more given to variegated behaviour in the matter of currents than places inland. The knowledge of this fact is, I take it, one reason why so few up to the present have attempted cross-Channel flight, though there are some dozens of men whose machines could get the distance, so far as mere distance is concerned.

Inland, with a horizontal wind, every obstruction gives rise to an upward current, as you may observe if you notice birds hovering over the edge of a quarry, or even over a high bank, or a house, for no bird can hover (or soar, in the correct sense of the word) except in an

AIR CURRENTS. (*Continued*).

upward current. Upward currents of a mild sort are even created by hot air rising out of a confined valley when the sun is beating down into it, and a hawk, which is a real soaring bird (as distinct from most British birds, who generally "flap"), will perform his familiar "immobility" trick of hovering motionless over one spot even in such a moderate up-draught as that. In such a case there must, of necessity, be a down-draught of cold air down the side of the valley to make up for the hot air which is rising. A strong down-draught is also caused by a horizontal wind blowing over the top of a hill and down the other side in this way—



especially if the top of the hill is of "easy lines," to use a nautical term, so that the wind follows the surface as a natural stream-line. These few illustrations will give a fair idea of how wind currents run and a few of the causes of them. There are innumerable other prime and subsidiary causes for the vagaries of the wind, and I give these few more to provide food for thought and to suggest ideas for further personal observation than with any notion that they even begin to exhaust the subject.

Now, the upward current is obviously the one most to be desired either by an actual flying man or by an experimenter with models, for with the right kind of current in an upward direction, a model or an aeroplane can not only travel forward without any power beyond gravity, but it can actually rise while falling.

AIR CURRENTS. (*Continued*).

Take, for example, a machine which, gliding at its own normal angle, falls at the rate of 3ft. a second. If that machine should strike a current with an upward velocity of 5ft. a second it will rise steadily at the rate of 2ft. a second, for it is raised 5ft. for every 3ft. it falls, so that it has a balance of 2ft. a second in its favour. If this rising wind has, at the same time, a strong horizontal movement—that is to say, if it is rising very rapidly, but at an acute angle with the horizontal—the machine will be blown backwards while rising all the while ; but if the wind is rising nearly vertically the machine will rise and will soar away from its starting point. I have seen this happen with Mr. Weiss's bird-like models, and it is most uncanny when first seen, to watch a machine which you know has no motive power rise and sail away from you at the same time. The behaviour of these models in varying currents is most interesting and highly educative.

An excellent example of the effect of a downward current was seen at the Reims Meeting. The first turning pylon, after passing the Stands, was on the brow of a slope, and thence the ground fell away gradually to a point about half-way to the next pylon, a matter of perhaps two miles away. Whenever there was anything approaching a breeze it blew from the Stands over the brow of this slope (it could not be called a hill), and evidently it blew in exactly the way shown in the preceding illustration, for machine after machine, if flying at all close to the ground, would pass the Stands in full flight, would clear the brow of the slope, and, after turning to the left round the pylon and dropping down into the hollow, would be forced to land just where the ground began to slope up to the next pylon. Some of the drivers were evidently under the impression that their machines were not lifting properly, but machines which always flew high, such as Latham's Antoinette and Paulhan's Voisin, never descended into the hollow, as they kept above the downward drift all the time. Glenn Curtiss told me at the time of this peculiar current, adding that when one had crossed the middle of the hollow the wind on the other side was blowing in the

opposite direction. Now Curtiss habitually flew at a middle height, so that he was never actually beaten down into the hollow, therefore I imagine that the wind he met on the other side must have been an eddy current, formed by the air rising out of the hollow, possibly a slight curl from a ridge of high ground to the right of the course added thereto, and the still level drift of air at a different velocity overhead. However, the experience is interesting, and shows how much reserve power and speed is necessary before flying machines become practical. Dr. Hutchinson tells me of a similar example of wind current in ballooning, where the balloon in which he was travelling crossed the brow of a slope on one side of a wide valley, descended right into the valley, keeping all the time almost the same height above the ground, and finally rose again at the other side, following the contour of the valley the whole time.

CHAPTER VII.

THE EFFECTS OF AIR CURRENTS.

IN a pamphlet printed for private circulation by Mr. Weiss are some diagrams of the behaviour of soaring models in different conditions of air currents, and he has kindly given me his permission to reproduce these. They show more clearly than anything I have yet seen how the flight of a machine is affected by variations of current from the horizontal, for it must be remembered that even in a power-driven machine the effect is the same, though the degree will be lessened in proportion to the power available to counteract it.

In each case


X A is the speed and angle of normal glide in still air.

X B is the velocity and angle of wind current.

X C is the speed and angle of resulting flight.

The arrow-heads show the direction in each case, and in all cases the angles are exaggerated for clearness, X being the starting point.

Mr. Weiss remarks in a footnote that he has seen glides under all these conditions hundreds of times. I may add that I have myself witnessed many of them in Mr. Weiss's company, and that the secondary diagrams (B_r, C_r) in the two "horizontal" diagrams are additions of my own to Mr. Weiss's diagrams.

 Now observe the effect of such currents on power-driven planes. In the case of fig. 1 a well-designed machine would practically be able to shut off power and coast *upwards*. Under the circumstances of fig. 2, to avoid being blown backwards, the only hope would be to alter the natural soaring angle of the planes and reduce the wing area, and then go full speed ahead, for extra speed (as I pointed out earlier in these remarks) without altered angle or area, would merely mean soaring higher

THE EFFECTS OF AIR CURRENTS. (Continued).

1.—IN THE CASE OF ASCENDING CURRENTS.

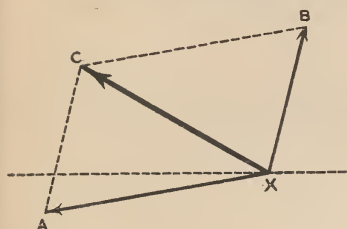


FIG. 1.

The wind blowing in the direction X to B, the model, travelling against the wind, rises and soars away in the direction of X to C.

FIG. 2.

The wind blowing strongly but more nearly to the horizontal, the model, started against the wind, will soar vertically upwards, or may be blown backwards still rising.

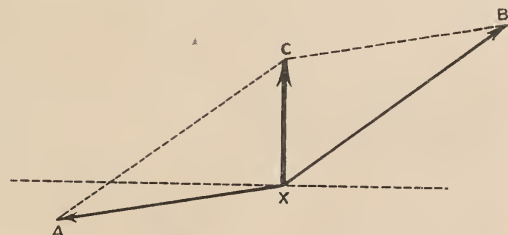


FIG. 3.

Model travelling *with* the wind will rise if direction of wind is sufficiently vertical, and its speed will be increased.

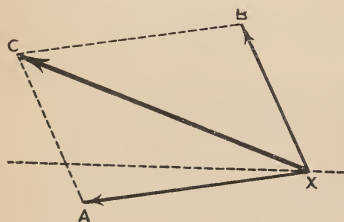
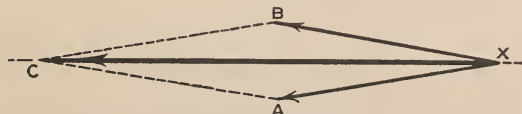


FIG. 4.



Or the model may fly level at a greatly increased speed, or, if the wind is more nearly horizontal and not of sufficient power, the model may descend.

II.—DESCENDING CURRENTS.

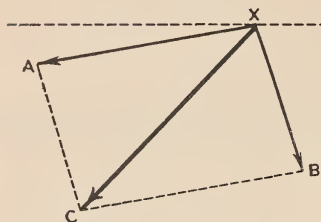
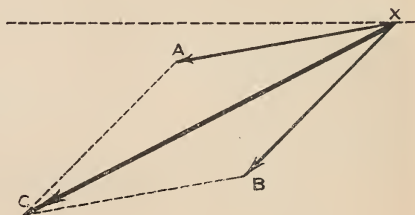


FIG. 5.

Model travelling *against* the descending wind X B sinks rapidly and possibly vertically.

FIG. 6.

Model travelling *with* the descending wind gives a better glide than in the other case, but it must descend in any case.



III.—HORIZONTAL CURRENTS.

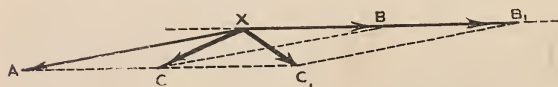
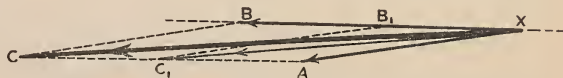


FIG. 7.

Model travelling *against* a horizontal wind has its speed retarded (as to C) and its drop increased, or if the wind is very strong it may be blown backwards as to Cr.

FIG. 8.



Model travelling *with* strong horizontal wind has speed increased and drop reduced. With less wind (as X B₁) the reduction of drop is not so good (X C₁).

and higher still. Of course, doing so would mean in time getting above the up-current, and then it would be possible to slide down its back, so to speak, with power practically shut off. If the conditions of fig. 3 prevailed one could again go ahead without power; and if those of fig. 4 it would probably be necessary to turn on half-speed just so as to get the necessary excess speed over the wind to give a lift. In the case of fig. 5 it would be evidently a case of going full speed ahead with every ounce the engine could raise, for the task before the machine would be to catch and force downwards (*vide* the second chapter of this book) sufficient air to sustain the machine, and, as the current is already travelling downwards, the machine would have to travel at a terrific pace to catch the necessary amount of air and impart to it the necessary *extra* downward speed in excess of what it already possesses. And besides this, the downward current would tend to destroy that useful partial vacuum on the top surface which is formed in a plain horizontal wind or in still air. Under these circumstances it will easily be seen that a tremendous reserve of power will be necessary, and it will also be necessary to alter the angle of the main planes in an upward direction (not merely to steer upwards with a horizontal rudder) so as to catch more wind. The circumstances of fig. 6 show a somewhat alleviated condition of the same state of affairs, with an enormously increased "earth" speed in order to catch up with the wind, though the "air" speed of the machine (*i.e.*, the speed of the machine in relation to the surrounding air) might not have to be so great. Fig. 7 shows a very ordinary case; it is merely a matter of whether the wind speed is so great as to carry the machine backwards, if it cannot reduce its wing area when extra power is turned on. Fig. 8 is the simplest of the lot, once the machine is off the ground and has got up sufficient "air" speed to catch the wind and exceed it by enough to lift the machine and keep it up. Of all conditions, therefore, that of fig. 5 is by far the worst if encountered when off the ground, for unless there is plenty of reserve power a very sudden descent will follow.

THE EFFECTS OF AIR CURRENTS. (*Continued*).

It will have been noticed that in all these circumstances a great deal depends on being able in an instant to alter the soaring angle of the machine, and at present designers are far from being agreed as to what is the correct method of doing this. As I have said before, in several machines there are little horizontal rudders (or dampers) in front of the main planes, with which the machines are steered upwards or downwards as desired. Maxim's colossal steam flying machine, which flew *under* rails (as well as over them), had a leading plane, which was intended to have a similar effect, but it is doubtful whether these really increase the actual lifting effect of the machine to any great extent, and I am inclined to think (correct me, someone, if I am wrong) that if they were forced into a downward current, even when inclined upwards to their utmost, they would still force the nose of the machine downwards, owing to their lead and leverage over the rest of the machine. The other way of doing the vertical steering is by altering the centre of gravity of the whole machine, so that it is tilted upwards or downwards as the weight is shifted, but the discussion of that point must wait for another chapter.

CHAPTER VIII.

CENTRES OF GRAVITY AND OF PRESSURE.

IN previous chapters I have referred to the matter of altering the soaring angle of an aeroplane. There is a variety of ways of doing this, but all, to be efficient, depend on one result, namely, the alteration in the relative positions of the centre of gravity and the centre of pressure of the machine. I must assume that everyone who reads this book knows what the centre of gravity of a body is, for space does not permit of my going into a dissertation on elementary physics. Now, just as every finite body has a centre of gravity, so every aeroplane must have a centre of pressure, which is the point on which the machine swings, so to speak, in the air. Now it is obvious, on that hypothesis, that if the centre of gravity gets in front of the centre of pressure it will pull the nose of the machine down, and will decrease the soaring angle if the pull is slight; and if the centre of gravity is advanced too much it will put so much pull on the front of the machine that it will get below any possible soaring angle, and will dive more or less straight down. On the other hand, if the centre of gravity is moved behind the centre of pressure the tail of the machine will drop, and it will present a greater angle to the wind. No doubt if the centre of gravity were moved too far back the machine (assuming it to be up in the air first) would slide down backwards, and, as it would not be designed to "go astern," the motion would resolve itself into a sheer drop. It is by altering their centre of gravity in this way that birds do their vertical steering. Darwin noted in "*The Voyage of H.M.S. Beagle*" that the condors of the Andes, which are one of the finest of the purely soaring birds, "moved in large curves, sweeping in circles, descending and ascending without once flapping. The head and neck were moved frequently and with force, and it appeared as if the

extended wings formed the fulcrum on which the movements of the neck, body, and tail acted." One may assume that these movements of the head and neck were made in order to alter the position of the centre of gravity in relation to the immobile wings. Mr. Weiss, some years ago, proved this for all practical purposes by catching some small birds alive. Some of them he fitted with little paper collars held in position by a piece of cotton for a tie, the collars keeping their heads extended slightly forward. Others he fitted with bearing reins of cotton held in position on the top of their heads and the middle of their backs with cobbler's wax or some such substance. The birds with the collars fell forward when they attempted to fly, and those with the bearing reins fell backwards. On the removal of their harness the birds flew away none the worse for having been made the subject of scientific experiment, so I hope the S.P.C.A. will not raise any objections.

A SUGGESTION.

This would seem to suggest that something might be done, especially on monoplanes, by providing the driver with a sliding seat (controlled by a lever, for it would never do to have him shifting his position inadvertently when he wanted to stretch his legs). The shifting of the driver's weight very slightly fore and aft would probably give the necessary variation for vertical steering. Shifting the engine itself in the *fuselage* would have a similar effect, and Mr. Harold Piffard is working on these lines.

I presume my readers will have realised that the centre of gravity and the centre of pressure must be situated, to begin with, in the same vertical plane, otherwise the machine would have a "list" to one side or other and would not fly at all, or, if it did manage to rise, would soon come down sideways.

The alternative to shifting the centre of gravity is, naturally, shifting the centre of pressure, which is presumably what takes place in existing flying machines. When the forward damper of a Wright or Voisin machine is inclined upwards it takes on more pressure, and brings the centre of pressure forward of the centre of gravity,

A SUGGESTION. (Continued).

so that the machine as a whole tilts upwards; when it is depressed it produces a negative pressure (*i.e.*, a negative lifting pressure), and the centre of pressure recedes, allowing the machine to tilt downwards. It seems to me, however, that this method has the disadvantage of a lot of extended working parts which add to wind resistance, and that the dampers themselves add more to resistance than they make up in efficient lifting power.

VARIATION OF PRESSURE CENTRES.

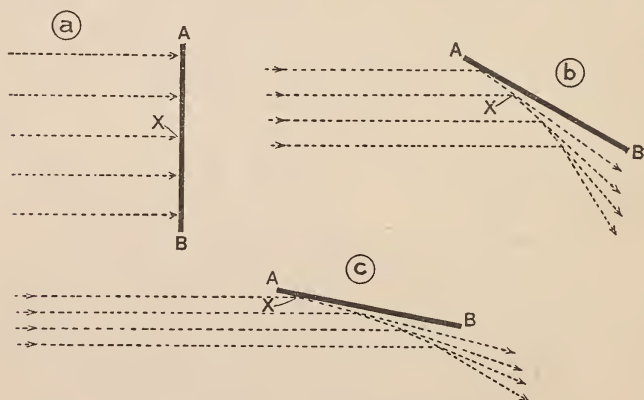
There is another very important point which needs consideration here. That is the fact that the position of the centre of pressure varies according to the angle at which the machine is flying, and also according to its speed. As the flying angle (or angle of attack) decreases, the centre of pressure comes forward towards the front edge of the plane. Similarly, as the speed increases, the centre of pressure comes forward. Naturally as the centre of pressure comes forward in this way, and gets in front of the centre of gravity, the machine has a tendency to rise.

This accounts for the fact that the critical speed of any one machine is practically its maximum speed, as mentioned in Chapter V. As I said therein, I will not attempt to explain this scientifically, not being a scientist, but the following very unscientific explanation may perhaps suggest the why and wherefore of this phenomenon.

Assume, for example, that A B (*fig. a*) is the side elevation, or end view, of a plane standing up vertically with the wind blowing against it, as shown by the dotted lines. Now it is fairly obvious that the centre of pressure must be in the exact centre of the plane, as shown at X. Next, let us tilt the plane somewhat forward, as shown in *fig. b*. It is clear that the particular wind current which strikes the plane at the top edge will get in its full pressure, and will then endeavour to reflect itself at an angle equal to its angle of incidence. But before it can reflect it is met by the next stratum of wind which compresses it against the plane. Incidentally the compressed

VARIATION OF PRESSURE CENTRES. (Continued).

stratum acts as a cushion and prevents the second current from striking the plane with its full force. Each successive stratum, therefore, is thus reflected and cushioned at the same time till, at the bottom of a long section (or deep) plane, the lower strata are simply diving into very resilient cushions of slightly compressed air, which already have a rapid motion outwards and downwards past the rear, or lower, edge of the plane, and so these lower currents do very little work at all, and consequently the effective pressure is delivered, as at X, nearer the front of the plane. Which accounts for the fact that very narrow planes are so much more efficient than deep ones.



Now, obviously, as the angle increases, as in *fig. c*, the wind currents will strike a more glancing blow and will glide off more easily. The first stratum will thus have a still greater advantage over the lower strata, which by this time are doing next to nothing in the way of supporting the plane. Consequently the effective centre of pressure comes quite close up to the front edge. It is, of course, easy to see that when the plane is absolutely horizontal to the wind the centre of pressure will be exactly in the middle of the front edge and there will be no lift at all, consequently the centre of pressure varies all the way

VARIATION OF PRESSURE CENTRES. (*Continued*).

from the centre of the plane to the centre of the edge as the plane is inclined forward from vertical to horizontal.

So much then for variation of angle. Let us next consider how variation of speed affects the question. I have already pointed out that in order to get a high speed a small flying angle is necessary. Consequently, as the speed gets up, the angle is decreased and the centre of pressure comes forward, as shown. But with increased speed comes increased pressure on the plane wherever the plane is hit by "clean" air (*i.e.*, air not cushioned by other reflected air). Also with increased speed comes more rapid and powerful reflection of such wind currents as are reflected, and these powerfully reflected streams have the more power in themselves to cut off and deflect, and so make ineffectual, the lower currents which would otherwise take effect on the rear portion of the plane.

Thus, as the decrease in the flying angle brings the centre of pressure forward, the increase in speed increases the amount of pressure on that centre, and increases the lift at the front of the plane, necessitating a still smaller flying angle to keep the machine flying horizontally, and thus bringing the centre of pressure still further forward, the combined process repeating itself till finally a point is reached at which the centre of pressure reaches the edge of the plane and the angle vanishes (*i.e.*, the plane becomes horizontal), and the machine has no lift. Thus, if forced beyond its critical speed and angle, the centre of pressure will get over the plane instead of under it, and the machine will dive head first. It is very probable that this was the cause of the accident which killed Eugène Lefebvre. As his machine had no tail plane to steady it fore and aft, a forward dive would allow the pressure centre to jump instantly on to the top of the plane. Once a machine has started to dive in this way, especially if the dive is caused by holding the machine down with an elevator rudder, it would be very difficult to bring it back again, except by shifting the centre of gravity back suddenly and pulling the tail down. That is why I like the idea, at any rate in a small machine, of shifting the centre of

gravity. It is also a point in favour of doing one's vertical steering with a tail plane which carries part of the weight, for, in the case of a sudden dive, the tipping down of the tail plane would take the lift off the tail and leave the whole weight of the *fuselage* (or tapered after-frame) to pull the machine right end up again.

ON HORIZONTAL STEERING.

This portion of the subject leads us, naturally, to the consideration of horizontal steering and its effects. Horizontal steering is done, as a rule, by an ordinary vertical rudder at the stern of the aeroplane, the said rudder dragging the machine round just as the rudder of a ship does. There is, however, a vast difference in the effect, for, owing to the wide spread of the wings, the outer wing at the turn will travel much faster than the inner one, so getting a greater lift and pulling the centre of pressure to that side, with the result that the machine has a tendency to drop to the inside of the curve. In the case of M. Blériot's early monoplanes, this actually happened more than once. To counteract this effect of the steering various devices are adopted. In the Wright machines the rear of the outer ends of the planes is made so that they can be warped downwards, so causing greater resistance. In turning, the end of the inside wing is warped, and the extra resistance gives a lift, which compensates for the extra lift due to the extra speed of the outer wing, and so the machine is kept on an even keel and is prevented from sliding to the inside of the curve. Incidentally the resistance of this warped wing puts a drag on that side of the machine and assists the rudder. Esnault-Pelterie uses a wing (on his monoplane) which twists bodily, a very clever affair. An exactly similar effect is produced in the later Blériot monoplanes by having adjustable tips to the wings, the tip of the inside wing being tilted upwards on a rod which runs thwartwise through the centre of it.

In the latest Blériots the fixed tail plane carries the ailerons (or movable tips) which are used independently

as stabilisers, or together as elevators. The earlier Antoinettes, of the No. IV. type, carry ailerons behind the ends of the wings; but in newer types, such as the No. VII., the whole wing is warped. The more expert fliers with the Wright type of machine, such as the late Eugène Lefebvre, for example, use the warping wings differently from the method described above. In turning a corner they first of all steer round with the rudder; this throws the outer wing up, as set forth; then they warp the *outer* wing, throwing it still further up, and thus make a banking, or seating, for the machine on the air at a very big angle from the horizontal, trusting to the centrifugal force generated by their own speed to hold them into the air and to prevent them from slipping down inwards. This manoeuvre must be executed at a fairly high speed to ensure the centrifugal force being sufficient to hold the machine up against the force of gravity. On the Howard Wright (the English) biplane, and others, pieces are cut out of the rear of the wing tips and replaced by movable shutters, known as "aileron," which can be pulled down to give the necessary extra resistance. I have often heard people who only had hazy ideas about aeroplanes say that these "aileron," and warped planes, were for the purpose of steering. Such, however, is not the case, as I have explained above.

HEAD STEERING.

Further in relation to this question of steering, it is worthy of note that the machine with which G. H. Curtiss won the Gordon Bennett Cup this year (1909) had a fixed horizontal and vertical tail, the steering being done by a triangular rudder carried in the centre of the biplane elevator, the base of the triangle being presented to the wind, with half the triangle above the upper plane of the elevator and half below it. This method of steering appears to me to have much the same advantage that forward steering has on a car or cycle, namely, that the head of the machine is brought round at once, spinning on its tail, and the rest of the machine follows it, whereas with rear rudders the tail of the machine pays off and

appears to set up a considerable amount of leeway before the machine picks up its new course. I judge this assumption to be correct, because certainly Curtiss came round the turning pylons at Reims in a cleaner sweep than any of the other competitors. Apparently other designers stick to the tail rudder because of the apparent likeness of the machine to a boat. This seems entirely a false analogy which may eventually be discarded.

It is extremely doubtful whether even birds steer with their tails. Several keen observers of my acquaintance deny flatly that they do so. As I have already stated, it is fairly certain that a bird gets his elevation by shifting his head, and it is at least probable that a bird uses his head for a rudder. It is noticeable that almost all birds have very flat sides to their heads, and this flatness would appear to afford excellent deflecting surfaces for steering purposes. I commend this idea to those of my readers who seek to solve the problems of flight by observing the methods of birds.

THE EFFECT OF MOMENTUM.

In connection with the subject of turning there is another very important matter to be considered. That is the effect of the inertia of the machine itself. I have already explained that when once one is free from the ground, and has absolutely "upped anchor" so to speak, the "air speed" of the machine is quite independent of the "land speed," *i.e.*, one might be doing 10 miles an hour backwards against a 40 mile an hour gale and still have an "air speed" of 30 miles an hour. It is, however, necessary to remember that one is still "anchored" to an extent by the force of gravity and the consequent inertia of the machine itself. That is to say, a certain amount of extra power is necessary to change the momentum of the machine from a lower speed to a higher speed quite apart from the speed necessary to move it through the air. As I have already said, once one is free from the ground the same amount of power is necessary to drive a machine at a given speed through the air whether it is travelling with the wind or against it; the "land speed" does not really matter. Where the inertia of the machine makes itself felt is in turning.

TURNING DOWN-WIND.

TURNING DOWN-WIND.

Take for example the case of a machine whose normal travelling speed (or soaring speed) is 30 miles an hour. Suppose that machine to be starting from rest against a 20 mile an hour breeze. As soon as the machine reaches a land speed of 10 miles an hour it will begin to soar, and with the engine running at that speed it will continue to make a steady 10 miles an hour against the wind, though its actual wind speed will be the necessary 30 miles an hour. Now notice that the momentum of the machine is only the momentum of the mass of the machine produced at a speed of 10 miles an hour. Consider then what happens when the machine begins to turn. In order to continue soaring when the wind is aft the machine must travel 30 miles an hour ("air speed") faster than the wind, which is itself travelling at 20 miles an hour ("land speed"). Which means that the "land speed" of the machine must rise, in the course of the turn, from 10 miles an hour to 50 miles an hour. Now, the difference between the momentum of a machine weighing, say, 1,200 lbs. at 10 miles an hour and the momentum of the same machine at 50 miles an hour is pretty considerable, and if the turn is taken at all quickly the engine will have to work rather hard for a short while to overcome the inertia of the machine and pick up the extra momentum. If the extra momentum is not picked up, it simply means that the machine will not be going fast enough when she turns tail to wind. Instead of doing 50 miles an hour she might be doing 40 only, which would reduce her "air speed" from the necessary 30 miles an hour to a mere 20, and she would drop.

OTHER CONSIDERATIONS.

Of course the machine in picking up the extra momentum will receive considerable assistance from the wind itself, for it must not be forgotten, that as the machine comes round the curve the wind in which she is travelling is still making its 20 miles an hour, so that when the machine is half-way round the curve she is going ahead at 30 miles an hour ("air speed"), and making lee-way

OTHER CONSIDERATIONS. (Continued).

towards the inside of the curve at 20 miles an hour ("land speed"), from which, however, must be deducted a small amount for the centrifugal force acting on the mass of the machine as she takes the curve at her original 10 miles an hour ("land speed"). Probably at such a low speed it would be a very small amount, so one might reckon on the 20 miles an hour lee-way. Thus the momentum of the machine has already reached that produced by a speed of 20 miles an hour, so between the half-turn and the full-turn the engine has got to pick up the remaining 30 miles an hour. In practice, however, the driver would probably open the engine up wide as he began to turn, so that he would soar considerably at the beginning of the turn and drop gradually as he came round, the drop and the propeller acceleration together giving the necessary extra speed and consequent extra momentum as he finished the turn. This turn against the wind is the first turn the budding aeronaut has to make, after he is past the stage of only flying in dead calms, for he will naturally start his machine against the wind with a low "land speed" rather than with the wind with a high "land speed."

TURNING UP-WIND.

The converse of this turn, *i.e.* flying down wind and turning up into it, is probably less dangerous in one way, and yet it seems to call for more judgment. Consider what happens to a machine such as I have hypothesised with in the previous case. The machine is flying down wind with a "land speed," and consequent momentum, of 50 miles an hour. When the turn comes, neglecting other forces, the machine would swing round with the momentum due to a speed of 50 miles an hour into a 20 mile an hour breeze. The result would be that she would be going too fast, and would shoot up like a rocket till she lost her momentum, and then she would glide gently down again.

So far it would be fairly simple, but when one comes to consider the other forces at work, one sees where the driver's judgment comes in. First of all, the centrifugal force generated by the momentum of a 1,200 lb. machine at 50 miles an

hour would be something terrific, and the machine would make a tremendous amount of lee-way towards the outside of the curve from that cause alone. Then the wind is also making 20 miles an hour towards the outside of the curve so the machine would continue to make progress down wind for some considerable time after the turn had begun. Therefore the driver would have to exercise considerable judgment as to where he began his turn, for if there happened to be buildings or trees in his course he would be quite likely to take them broad side on during the turn if he put off the beginning of his turn a few moments too late. It will thus be seen that even when in the air and clear of the ground one's "land speed" is of some account.

FORE AND AFT STABILITY.

Connected with the subject of steering is the question of the automatic, or inherent, stability of the machine both fore and aft and laterally. Mr. Lanchester christens the fore and aft stability "phugoid" (or flight-path) stability. A good many machines, notably the Voisins, are made with very large horizontal tails to give "phugoid" stability, but the Wright machine has none and is lacking in automatic stability. Mr. Lanchester fitted all his models with quite large horizontal tails and worked out numerous elaborate calculations to show their great effect on the longitudinal stability and on the "critical velocity," or natural speed, of "aerodones" (*i.e.*, soaring machines in particular) or "aerodromes" (flying machines in general). Against this Mr. Weiss's models have no tails at all, either horizontal or vertical (as rudders), yet they have no fore and aft oscillations, and they steer very nicely horizontally by slightly altering the flexible tips of the wings. Altogether it is hard to say who is right in this respect, for birds do not help us, because pheasants and partridges fly about equally well allowing for differences in weight and training. The only thing we do know about it is that the first-class soaring birds, such as the albatross and condor, have absurdly small tails, though Mr. Lanchester shows that the webbed feet of the albatross are carried straight out be-

hind and act as an auxiliary to the tail. Time alone can show which of the two schools of thought are really right.

It has been observed that most models fly in a series of waves, and on these waves Mr. Lanchester has founded his "phugoid theory." Roughly, it amounts to this, that every flying machine (or rather soaring machine) has a certain phugoid path peculiar to itself if left uncontrolled. In some designs of machines the waves in this phugoid path have a tendency to increase, in other designs they have a tendency to decrease (or "damp out") and turn into a straight line. Now in the case of increasing waves there is the danger that, as the wave increases, the machine in rising to the "crest" of the wave may come so nearly vertical as to stop on its upward path and slide down backwards. In the case of the decreasing waves the oscillations (fore and aft) damp out and the machine simply glides to earth. Of course, in a power-driven, humanly-controlled machine so long as the human control and the power are in proper working order the machine is safe, but correct design would be that in which, if the human control were put out of action say by sudden faintness or by a wound, the machine would ultimately glide to earth uninjured except for what it might hit after landing. The Voisins claim that with their machines you can shut off power 60ft. from the ground and the machine will glide to earth at a proper landing angle. I am told by a mathematician who understands the phugoid theory that 60ft. is not a sufficient test. According to the theory, a machine of the Voisin design has a wave length, from crest to crest of its phugoid waves, of some 1,600ft., and as it must pass three such waves to prove that the oscillations are damping out and not increasing, it would have to glide 4,800ft. to prove its phugoid stability. Assuming its gliding angle to be about 1 in 8, it would have to start its automatic glide from a height of 600ft. (not 60ft.) to prove its stability. So far as the Wright machine is concerned anyone who has seen even the kinematograph pictures of the machine in flight must have noticed how unstable it is in its fore and aft

FORE AND AFT STABILITY. (*Continued*).

direction, needing constant vertical steering the whole time. In fact, the whole machine is simply held in the air by the sheer skill of the driver. It is evident that before flying machines can become practicable vehicles they must have perfect automatic stability, both phugoid and lateral, for a driver will have quite enough to do to attend to his steering and his engine speed, without keeping the machine balanced as well and becoming a combination of motor driver and 'tight-rope walker. One can imagine easily how much, or rather how little, progress the motor car would have made if one had been obliged to balance it bicycle fashion, as well as drive it and steer it.

I have shown how the inertia of the machine itself operates in turning corners, and it would appear that the inertia of the machine will ultimately play a very important part in the stability of high-speed machines. Mr. Lanchester has already been quoted as saying that 90 miles an hour appears theoretically to be the safe flying speed of the machine of the future, that speed being assumedly double the speed of any gust which is likely to be met. Stated in the most unscientific language, this means that a machine at this speed will acquire sufficient momentum to carry it safely through any gust which may strike it. Suppose, for example, a machine capable of such a flying speed were flying against a 45 mile an hour wind (which is nearly a full gale), it would still have a "land speed" of 45 miles an hour. That is to say, its momentum would be the momentum acquired at 45 miles an hour. Any gust which struck it would scarcely be likely to exceed 60 miles an hour, or merely 15 miles an hour in excess of the normal wind speed. This would then be equivalent to a machine flying at 45 miles an hour in still air meeting a gust at 15 miles an hour (roughly 22ft. a second). A heavy machine at such a speed would probably charge through such a gust without noticing it, or at any rate it would only cause a slight deviation from its path, there being still a clear excess speed of 30 miles an hour to spare.

A simple example of this idea may be found in a boat, or more particularly in a punt, which, having flat

FORE AND AFT STABILITY. (Continued).

surfaces, offers more resistance than a boat, on any river which has a fairly rapid tributary stream running into it. Coming up-stream with little momentum, although the "water speed" (as opposed to "land speed") may be quite considerable, as the bow of the boat enters the tributary stream it will be caught, and probably thrown right across the main stream. Coming down-stream, on the contrary, the momentum is very much increased, the "water speed" being added to the "land speed," and when one meets the tributary stream the momentum of the boat will carry it right through the other stream without any noticeable deflection from its course.

On this assumption it would seem that the safe flying machine of the future will be a very fast and heavy machine, *i.e.*, a machine which will acquire a large amount of momentum.

CHAPTER IX.


LATERAL STABILITY.

I HAD to omit any mention in the last chapter of the question of lateral stability, or what would be called "roll" in a boat. This really seems the most difficult problem of the lot, and it is a very serious problem, for if an aeroplane should tilt much, laterally, it will obviously slide down sideways, much in the way I indicated in discussing the effects of "ailerons" in turning corners. M. Esnault-Pelterie and M. Blériot and M. Levavasseur, of the Antoinette Company, are trying the effects of fins along the backs of their machines, and Mr. Lanchester used fins on his small models for the same reason.

These fins act somewhat similarly to a deep keel or a centre-board on a boat, only they are on top instead of underneath. The Wright machine depends absolutely on the skill of the driver in manipulating his warped planes to keep the machine level; and the Voisins depend on the vertical planes between the main planes, which vertical planes make the machine into a kind of box-kite. Mr. Weiss's models have nothing of this kind, but the wings have a downward droop similar to the droop of the wings of a swift when soaring—a phenomenon which was observed by Mr. Lanchester, and is commented on in his book on "Aerodionetics." This droop seems very effective, for I have seen these models encounter very strange side-gusts without capsizing; in fact, they cannot be capsized, and they right themselves like a lifeboat if launched carelessly. Mr. Weiss seems in these models, which range in size from a 5 lb. model up to one carrying 140 lbs. of sandbags, to have solved the problem of automatic stability, and I am hoping ere long to see his full-size motor-driven machine, which was shown at the Aero Show, in actual use.

Mr. Lanchester's theory on this subject reduces roughly to this. If the wings of a soaring, or gliding, machine are curved upwards in the form of a bow the

machine certainly has a tendency to travel in a straight line, but it will have also a tendency to roll badly, the bow of the wings forming, so to speak, the path of a pendulum. I may suggest that, strictly speaking, the roll so set up is not so much a roll as a sideways slide, somewhat similar to the slide of a round-bottomed boat as one leans to one side or the other of it. We call this a roll, but if one watches, one sees that in reality the bottom of the boat is revolving round the centre of a circle formed by its own bottom. A flat-bottomed punt does not roll in this way because the flat bottom has to displace the water instead of merely sliding past it. In a somewhat similar way an aeroplane with wings bowed upwards will roll badly, whereas a perfectly flat machine will roll less. If then the wings of the machine are bowed downwards the roll will be minimised. Mr. Lanchester proves this mathematically, but I have only attempted to suggest a line of thought which may help experimenters. In this connection it is interesting to note that Dr. Graham-Bell's *Silver Dart*, with which Mr. McCurdy has flown some twenty miles or so at a stretch in Nova Scotia, is a biplane, in which the upper plane is bowed downwards and the lower plane bowed upwards. I have been unable to obtain as yet any exact details of the machine, but so much at least is clear from her photographs. One is tempted to think that the opposed curves of the two planes would counteract one another, but, be that as it may, the machine certainly flies better than anything else, except the Wright machine when driven by Wilbur Wright, and it is, I believe, the product of a British colony although fitted with an American engine.

In the Antoinette machines, which are certainly the most "eyeable" fliers of to-day, and are second to none in the matter of lateral stability, the wings, instead of being in a line with each other, are tilted upwards, and given what is technically known as a dihedral angle, that is to say, they are set in relation to one another as a widely open V, thus . According to Mr. Lanchester's theory this should set up a roll,

just as if the wings were curved upwards, but in the case of the Antoinette it does not appear to do so. There is no doubt that this formation decreases somewhat the lifting efficiency of the wings, but M. Levavasseur believes this loss to be more than compensated for by the increase in stability laterally, and, to anyone who has seen Latham flying, the belief seems to be fully justified.

However, this problem of automatic stability is rather beyond anything that can fairly be called "first principles," and belongs to a somewhat advanced stage of the science. The early stages do not seem to go beyond fin-keels, box-kites, dihedral planes, and "ailerons." It seems natural, however, that better stability can be obtained by keeping the centre of gravity somewhat below the centre of pressure, and many of the existing machines seem to be deficient in this respect, owing presumably to defects of design.

THE GYROSCOPE AND ITS POSSIBILITIES.

One hears so much about gyroscopes in these days that I can hardly leave the subject of stability without saying something about the possibilities of the gyroscope in relation to aeroplanes. The fascination of the gyroscope seems to be that very few people know anything about it, and those few know very little. That saying is not my own opinion; it is practically word for word the dictum of one of the leading authorities on the gyroscope. It is true that there is a great deal of more or less abstruse mathematical literature in existence on the subject, and I believe it is possible for those gifted with a taste for mathematics to work out more or less exactly what will happen to a gyroscope under given conditions, and, conversely, what weight and speed of gyroscope is necessary to produce certain desired effects. It is equally true that much remains to be discovered, so I take it that my informant knew what he was talking about, even if he purposely understated the amount which is really known, in the desire to emphasise the abstruseness of the subject.

The theory of the gyroscope is a very deep and complicated subject, but the simplest possible explanation of it

THE GYROSCOPE & ITS POSSIBILITIES. (*Continued*).

is somewhat as follows : Suppose you take a weight on the end of a piece of string and swing it round and round ; centrifugal force makes that weight tend to fly off at a **tangent**, and the string is kept taut. Evidently considerable force would be required to pull that string sideways out of the plane in which the weight is rotating. Now, if, instead of one weight, a wheel is spun, the centrifugal force of all the weights composing the rim of that wheel balance one another, so the only pull on the axle of the wheel is the mere weight of the wheel, so long as the axle of the wheel, and of course the wheel itself, is only moved in the plane of the wheel's revolution, or at right angles to it. But as soon as the axle of the wheel is moved at an angle, the effect is as if one tried to pull the string of the aforesaid weight to one side or the other, only, of course, the force needed is multiplied by the fact that you have weights all round instead of the one weight on a string. The same principle acts in the force which keeps a top upright so long as it is spinning. A simple test of the principle can be made by holding the ends of the axle of a cycle wheel horizontal and spinning the wheel. It will be found that the wheel can be moved up and down, or sideways (in a straight line with the axle), with ease, but that the axle can only be twisted to any other angle by a great effort. If one end of the axle is let go the wheel will still keep vertical (the axle being supported at the other end), as the force of gravity is not sufficient to overcome the gyroscopic force (which is the name given to the result of the pull of the centrifugal force of the rim) and to cause the wheel to fall owing to the unsupported end.

The latest manifestation of the gyroscope to catch public notice is the Brennan Monorail Car, which is an electric car running on a single rail with its wheels set bicycle fashion. In the car is a gyroscope revolving horizontally, with its axle set vertically to the floor of the car. This axle is hinged fore and aft ("set in gimbals" is the correct description, I believe), so that the front or back of the car can accommodate itself to gradients, but laterally the axle is fixed, so that the car cannot move

sideways out of the plane parallel to the revolution of the gyroscope. The force of a gyroscope depends on the weight and speed of the rim of the wheel (or "top") which forms the gyroscope; and in the Brennan Monorail Car the wheel is small and heavy, and revolves at an enormous speed, being itself an electric motor running on ball bearings. Gyroscopes are also used in torpedos to keep them running at a constant level and in a fixed direction, so that they may not be deflected from their course by small outside forces.

PRACTICAL EFFECTS.

The Germans tried a large horizontal gyroscope on a gunboat to prevent her from rolling, in the hopes of thus discovering a steady gun platform. The gyroscope was so effective that it broke the ship up. It is said also the destroyer *Cobra*, which was lost in the North Sea some years ago, broke her back through the high-speed turbines acting as gyroscopes and preventing her from pitching naturally to the seas. The turbines revolving vertically and thwartwise would allow the boat to rise and fall horizontally, or would allow her to roll, but would not allow the shafts on which they ran to tilt at an angle, consequently the boat could not pitch. Now, it is proposed to use gyroscopes to obtain automatic lateral stability in aeroplanes, the said gyroscopes to be revolved electrically or by gearing from the engine. In a way this would be quite easy, for a gyroscope revolving horizontally, and set in gimbals to allow fore and aft motion (for vertical steering), would hold the machine absolutely horizontal, if—that is the whole difficulty—the machine would stand it. But we must remember that though a solid mass of metal like a torpedo or a monorail car may stand the strain of a gyroscope holding it level by brute force, it has been pretty well proved that a ship will not stand it, and therefore it is fairly safe to assume that a light structure (such as an aeroplane is bound to be) would certainly not stand up to such a wrenching as it would get by being held level by its gyroscope and buffeted by stray side-gusts of

PRACTICAL EFFECTS. (Continued).

wind on its enormous surfaces. However, it is quite likely that before long the gyroscope may be adapted to give automatic control of the operating mechanisms of aeroplanes. The gyroscopic stabiliser invented by M. Marmonnier of Lyons, which I saw in a crude state at the Paris Aero Show, seems to have the makings of a really sound idea, and in its further development will be well worth watching. This machine is a combination of the pendulum and the gyroscope, and controls the ailerons or warps the wings of the aeroplane, so leaving the machine free to heel over to stray gusts or when turning corners, but bringing it back to an even keel afterwards.

THE MARMONNIER STABILISER.

Since writing the above I have obtained from Dr. Alfred Gradenwitz, of Berlin, a detailed description of the Marmonnier stabiliser, and the explanation given by him will be sufficiently lucid to the mechanically minded, though I fear it is somewhat involved for those who have not a taste for such things.

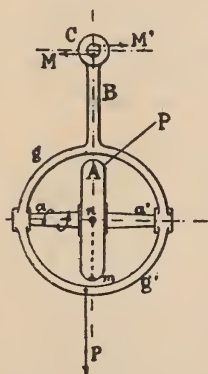
Dr. Gradenwitz writes: The successful trials of modern aeronauts have been rendered possible only by extraordinary personal skill and relatively favourable atmospheric conditions. In fact, the equilibrium of an aeroplane is naturally an unstable one, both in a longitudinal and transversal direction. In order to afford some safety, such an airship should accordingly be equipped with devices for assuring its equilibrium.

A Frenchman, Mr. L. Marmonnier, of Lyons, has invented a device which, it is hoped, will render the airship independent of the skill of the aeronaut as well as of atmospheric conditions. His apparatus is a combination of the pendulum with the top, and avoids the disadvantages of either while combining the individual advantages of both. (That is to say, it avoids the brutality of a fixed gyroscope, and the gyroscope is used, instead, to correct the tendency of a pendulum to oscillate for some time after it has once departed from the perpendicular.—THE AUTHOR.)

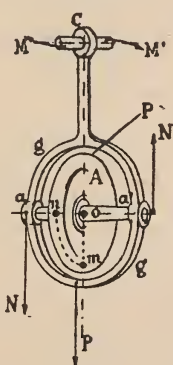
In order better to gauge the mode of action of this apparatus the behaviour of a gyroscope fitted to the end of a pendulum will be discussed on figs. 1, 2, and 3.

Supposing a flywheel A rotating round the axle a in the direction of the arrow to be given. The axle is fitted into a ring g fixed to the rod of a pendulum B which oscillates round the pivot C. The latter is arranged in such a way as to compel the pendulum to oscillate in a plane vertical to the flywheel axle. If some point m at the circumference of the flywheel be considered, this, according to the law of inertia, tends to keep up its motion in a

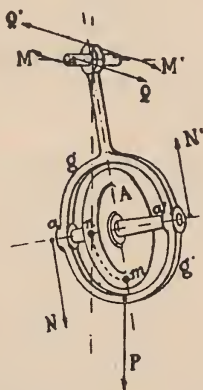
. Fig 1.



. Fig 2.



. Fig 3.



vertical upward direction $m n$. Supposing a couple of forces M to act on the pendulum pivot C, so as to cause the ring, at a given moment, to occupy the inclined, or rather "twisted," position represented in fig. 2. The point m at the circumference of the flywheel then, instead of following its original direction $m n$, tries to take up the position O. Now, under the influence of this change in direction, the ring g pivoted round C will turn round this pivot, *instantaneously* occupying a position slanting to the right hand as represented in fig. 3, and thereby producing another couple of forces $N N'$ which attacks at the two ends of the axle A A'. This is in turn equili-

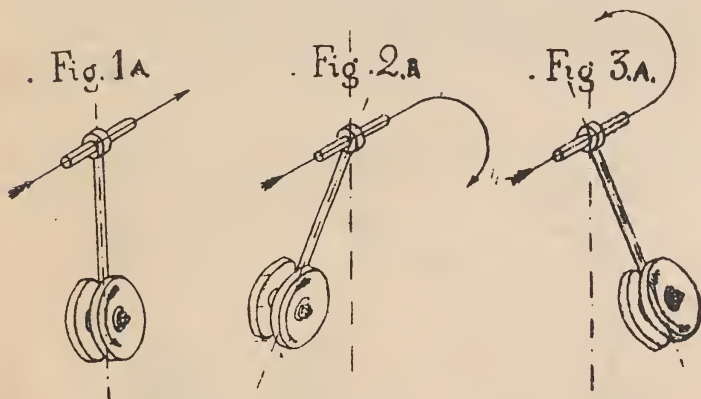
brated by a third couple, consisting of two forces of resistance $Q Q^1$ at the two ends of the pivot C (opposite to the components of the original couple $M M^1$). The inclination of the whole system with a given couple of forces is the more marked as the pendulum rod R is shorter, reaching a maximum in the event of the pivot C coinciding with the flywheel axle (that is, in the limiting case of a simple top devoid of any pendulum). The position of the pendulum, as represented in fig. 3, is maintained only while the couple $M M^1$ is acting on the pivot C ; as soon as this action ceases the pendulum, owing to the effect of gravity, returns to its vertical position. Moreover, any gyroscope mass which at the same time constitutes a pendulum mass is compelled by gravity to occupy a constant vertical position as long as the gyroscope maintains its motion in a given plane. Such a "pendulum gyroscope," during its motion in a given plane, remains vertical.

On this principle is based the construction of Marmonnier's stabiliser. The gyroscope of this apparatus consists of two flywheels rotating at equal speeds in the same direction and in parallel planes. The action of this gyroscope is fairly identical with that of a single flywheel.

We may now consider the behaviour of a "pendulum gyroscope" launched into space (say when swung on an aeroplane) in which the pendulum is capable of oscillating only in a plane vertical to the direction of motion while the flywheels B move in their peripheral plane. The influence of centrifugal forces $\frac{v^2}{r}$ will be provisionally left out of account.

After being launched \vec{v} in a straight line, the pendulum keeps perfectly vertical, independently of the direction of rotation of the flywheel, the speed of motion of the whole system, and any lateral displacement. In fact, the inertia of the top, in conjunction with gravity, prevents any change in the position of the pendulum. Any horizontal turning of the spindle on which the pendulum swings is attended by a right-hand or left-hand oscillation of the pendulum, according to the direction \vec{v} of motion and the

sense of rotation of the flywheels. This fact, inferred from the foregoing has been confirmed by actual practice. The top and pendulum body tends to leave the trajectory of the pendulum pivot, both in turning to the left and right, if the flywheels are rotating as in the figs. 1a, 2a, and 3a. The reaction of the gyroscope mass, however, tends to draw the pendulum into the trajectory described by its pivot, if the flywheels are rotating in the direction



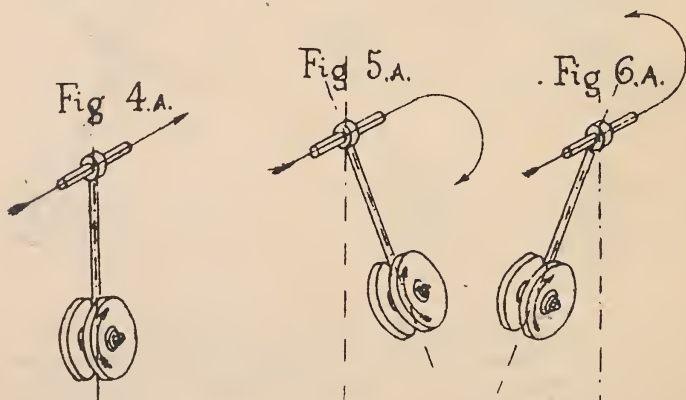
of the arrows (figs. 4a, 5a, and 6a). These reactions are the more energetic as the pendulum rod is shorter, and the weight, diameter, and peripheral speed of the flywheels more considerable.

Now the pendulum, under the influence of a turn, also undergoes another important effect, viz., the action of centrifugal force, which is the stronger as the speed of motion is greater and the radius of the trajectory smaller. In the case of the pendulum gyroscope, the centrifugal force, further, is proportional to the length of the pendulum. While this force is able to exert its full effect on a simple pendulum—which in a curve of small radius is thrown up into a horizontal position—the gyroscope pendulum offers considerable resistance.

It is thus possible to control the inclination of the pendulum at will, according as one or another of the two

opposing forces is allowed to predominate. By increasing, *e.g.*, the length of the pendulum, the centrifugal force is augmented; by adding to the weight and diameter of the flywheels as well as to their peripheral speed, the reaction of the flywheel masses is reinforced. And the centrifugal force can be either augmented or decreased according to the direction of revolution of the flywheels.

Now, in the case of an airship stabiliser, the centrifugal forces should be augmented in order to cause the pendulum to take up a slanting position with any turn. This inclination should be the greater as the speed is more con-



siderable and the turn of the aeroplane shorter, so that this may adjust itself to the air, readily negotiating any curves. This is obtained by keeping the speed of rotation of the flywheels about constant, while the centrifugal force is allowed to vary according to the speed of the aeroplane and the radius of its trajectory.

The stabiliser constructed on this principle is of considerable vertical rigidity in the case of a rectilinear motion while taking up when rounding curves, an angle depending on the speed and the radius of curve.

Though it is suitable for any system of aeroplane fitted with immobile surfaces, it is especially adapted to actuate

THE MARMONNIER STABILISER. (Continued).

movable surfaces, such as ailerons or flexing wings, intended for maintaining the equilibrium of the aeroplane. Whereas these surfaces have so far been controlled by hand, the Marmonnier apparatus affords an automatic control, thus rendering them independent of the skill of the aeronaut.

The first apparatus constructed according to the above system is $12\frac{1}{2}$ kgs. in weight, which, however, could be reduced considerably. It has been tested on an automobile, on which it was installed under the same conditions as on an aeroplane, undergoing no effect whatsoever outside of its own reflexes. The gyroscope and other organs of the stabiliser were actuated from the automobile motor through a friction clutch meshing with the flywheel and a double cardan shaft. The stabiliser was mounted freely on transversal rods provided with springs to damp any shocks produced by travelling.

CHAPTER X.

BODY WORK.

ANOTHER point worthy of attention, and yet one which seems to be singularly neglected, is the matter of body design. The Voisin machines have rudimentary bodies, more to shield the driver than anything else, and they stop short at the engine. The Wright, Farman, and Curtiss machines make no pretence to having a body at all, so the driver, engine, and small parts offer their full resistance to the wind, and that resistance is fairly considerable.

Mr. Howard Wright's biplane, as I have said before, has a body which really approximates to a bird shape ; so has the Weiss monoplane. The R.E.P., the Blériot, and the Antoinette machines have bodies, for, being monoplanes, it is almost a matter of necessity that the central part supporting the wings should be solidly built and in the form of a body. But even in these cases the shape of the body is more fish-shape than bird-shape. In his book on "Aerodynamics," Mr. Lanchester shows mathematically why the bluff bird-shape is more suitable for air travel than is the sharper, and apparently faster, fish-shape. Put in its simplest form it amounts to this. Since air is about 800 times less dense than water, an air body can afford to be more bluff as to its entry. On the other hand, since air is more viscous than water, an air body cannot afford to have the long slab sides of a fish or the round stern of a ship ; it must therefore have shorter and rounder sides and a very fine "run" aft, in order to minimise skin friction. To make up the necessary cubic capacity, therefore, the bird-body is bluff and somewhat beamy, and one may safely assume that ultimately the bodies of flying machines will approximate to the same shape.

A WORD AS TO PROPELLERS.

A WORD AS TO PROPELLERS.

The next point to need consideration is that of the position of the propeller or propellers. I do not propose to touch the subject of propeller design, for it is a specialised branch of the science, and by far the most intricate and purely mathematical part of the whole business. Still, without knowing anything about the actual science of the design, one may still judge propellers by results, as shown by their bench tests and actual performances on flying machines. It is admitted that the Voisin propellers only give about 40% efficiency, which is not surprising when one sees the lumps of iron on their surfaces where the arms are riveted to the blades, and the general clumsy appearance of the whole affair. This low efficiency goes a long way to account for the inferiority of the flights made by Farman and Delagrange as compared with Wright's distances, for the engines on the Voisin machines must be going absolutely "all out" to do as much as they do. The Wright propellers are supposed to give about 70% efficiency, and the performances of the machine seem to verify that statement, for Wright uses a less powerful engine than is used in the Voisin and other machines, though the comparative lightness of his machine, and the use of a launching machine to give the first thrust to lift the machine, allows the use of less power also.

There is much argument also as to the sizes and speeds of propellers. The Wrights use two large propellers, placed one on each side of the centre-line of the frame, running very slowly, and geared down by chains. The Voisins use a single small propeller coupled direct to the engine-shaft and placed in the centre of the frame which carries the tail. Our British Howard Wright places his propellers in the same position, but they are much larger, and run at one-third of the engine speed. They are both on one shaft, the after one keyed to the shaft and the forward one fixed to a sleeve running on the shaft; they are connected with one another by a very clever differential gear, which causes the propellers to be driven in opposite directions.

Esnault-Pelterie, Blériot, and the Antoinette all use

tractor screws fixed in front of the engine on the "nose" of their machines, and these screws, being keyed direct on the engine-shaft, are small high-speed screws, generally with four blades. It remains to be seen which is really the right system, though it is fairly evident that the propeller is preferable to the tractor screw. The reason for this is that if a screw is working in the "wake" of its vehicle, it has turbulent fluid in which to act. The "wake" always has a certain amount of "following" current in it, which is, so to speak, sucked along behind the vessel (this may be observed by hanging over the stern of a ship and observing the wake—the principle holds equally good for air vessels). Certain power is expended in producing this following current, and if the propeller can be made to work in it, some of that expended power is got back, because the screw is, in a way, working in a stream more favourable to its efficiency. If the screw is placed in the front of the machine, it has to do all the work without assistance, and the power expended in creating the turbulent "wake" currents is all wasted. There is, however, this much to be said in favour of a tractor screw. If a screw breaks, from any cause whatever, the broken blades will fly forward, for that is their natural path. In the case of a tractor screw they would thus be flung clear of the machine, whereas in the case of a propeller there is the danger of the pieces flying into the machine and smashing the framework, or, at any rate, cutting the control wires. This is a point worth considering, for at present burst screws are of fairly frequent occurrence.

The vertical position of the screws is a nice point in design, and will give a good deal of trouble to non-scientific experimenters. If placed too high they give the machine a tendency to dive, which has to be counteracted by additional tilt of the vertical steering, which means added resistance and consequent loss of efficiency. If placed too low they give a tendency to rise too much, with similar losses of efficiency. I am told that the correct position is on the same horizontal plane as the centre of gravity, which seems only natural, but I imagine some

A WORD AS TO PROPELLERS. (Continued).

of the extreme "rule of thumb" designers will have considerable difficulty in finding out the plane on which their centre of gravity is situated. Then there is, in the twin-screw machine, the further difficulty of getting the two screws to give such an absolutely equal impulse as to drive the machine straight without a continual pull on the rudder. I merely mention these matters as samples of some of the little troubles before the designer of flying machines. Apparently there are no hard and fast rules to guide him, so he must to a large extent depend on his own ingenuity and resourcefulness.

CONCERNING ENGINES.

On the matter of engines there is not much to say, though strangely enough there are more aero engines than there are flying machines. One can fly quite satisfactorily with a good car engine, though no doubt in time an engine will be evolved which will give more power for less weight, and, of course, the less weight one has to cart about the better in every way. Still, the engine is a matter for the motor engineer, and is not connected directly with the principles of flying. We have at any rate the consolation of knowing that our British motor designers are fully alive to the possibilities of flying machines, even if our capitalists are slow in commissioning the building of the machines themselves. The Wolseley Co. and Mr. F. R. Simms (the chairman of the Aero Section of the Society of Motor Manufacturers and Traders) both showed splendid aero engines at the 1909 Aero Show. The Green Engine Co. and the New Engine Co. are also turning out splendid examples of workmanship. The Humber Co. are also making aero engines worthy of the Humber name, and I am told that the Daimler and Napier companies have also something of this nature under consideration. There are besides a number of minor British firms which have aero engines built or building. The recent successes of the seven-cylinder rotary Gnome engine show that much may be expected from engines of this type. The future of flying depends very largely on engine development, and progress in this direction is quite satisfactory.

CHAPTER XI.

STARTING AND LANDING.

THOUGH the questions of starting and landing are not, strictly speaking, part of the theory or principles of flying itself, it will be as well to touch on them to some extent. Designers of flying machines are divided into two camps. Those who believe in starting by their own power by running along the ground on wheels and landing on wheels, and those who believe in starting off a launching machine of some sort assisted by a fixed power plant and landing on skates.

The only successful machine (as we measure success at present) of the latter type is that of the Wright Bros. This machine starts by being towed along a horizontal rail by a line which runs over a pulley at the outer end of the rail. The line is carried back along the rail over another pulley at the inner end of the rail up to a third pulley at the top of a 30ft. derrick (or *pylone*, as it is called in France). There the line is attached to a weight, which is released by a catch operated by the driver of the machine when he is ready to start. The weight, in falling, hauls the machine along the rail, and the line automatically frees itself from the machine as it reaches the end of the rail.

The advantages of this system are that the machine needs a shorter run to start it, owing to the extra power exerted by the weight, and besides, the machine need only carry a light engine powerful enough to sustain it in the air, and it need not carry sufficient power to overcome its own inertia when at rest. Also, large slow-running screws of long pitch can be used, which would be very inefficient when starting, but are highly efficient when once under way.

The disadvantages are that if the machine is forced to land away from its starting derrick it cannot rise again, even if fitted with wheels, and it has not much reserve

STARTING AND LANDING. *(Continued).*

power if it encounters a downward current or has need at any time of extra power. These disadvantages are, I believe, sufficient to prevent such a machine from becoming a practical "all-weather" machine, and condemn it to confine its operations to a limited area and to comparatively calm weather with only a steady breeze over flat land. It cannot, and dare not, tackle the varying currents and squalls of a hilly country. On the other hand, the wheeled machine, with plenty of power, can alight and rise again in a cross-country flight, as, I believe, Blériot did twice in his journey from Chalons to Rheims.

LANDING ONLY.

When one comes to consider landing only, the machine shod with skates has a decided advantage, for the big skates, which are generally about 12ft. long, will bridge ditches into which a wheel would drop and probably smash itself up, and the machine along with it. Also, when landing, the front of the machine is tipped up, so that the heel of the skate touches the ground while the toe is probably 4ft. or more above the ground. The toe would then ride safely over banks or mounds, which would catch and stop any wheel which could possibly be carried on a flying machine. When once landed, even on perfectly smooth ground, the skate will pull a machine up quicker than a rolling wheel would do. Also the skates are lighter and cheaper than wheels, with their tyres, spring shock-absorbers, and landing arrangements generally.

I think it highly probable that machines of the future will have comparatively light wheels for starting off smooth ground, and will have skates attached, which can be lowered below the wheels by the driver when about to land. When flying they will be tucked up out of the way, as a bird tucks up its legs. It is quite likely also that these machines will be adapted to start from launching machines as well, for such a start will save time and trouble when once the country is dotted with aero stations

(It is interesting to note that the machines now being built by Mr. Henry Farman are equipped with combined

LANDING ONLY. (Continued).

skids and wheels, and that the combination works excellently, the skids having saved his machines from several nasty accidents.)

FOR MILITARY PURPOSES.

The military machine of the future will almost certainly be a skate-shod machine starting from a launching machine. As Mr. Weiss pointed out recently in the paper he read to the Aeronautical Society, the military aeroplanist cannot expect to find level ground for starting and landing, whereas the Army Transport Corps can easily carry portable starting rails and derricks, and the necessary starting weight can be supplied by filling sandbags on the spot. The military scouting machine must necessarily be light and fast, so it cannot afford heavy tackle for landing, nor can it have a big wing-spread to allow it to rise and fly at low speeds. It must therefore be shot off like an arrow, and be prepared to land on any kind of ground on its return. A skate-shod monoplane is the only machine which seems to fulfil these requirements, and it will be interesting to watch the development of the military type as a thing apart from the sporting or passenger-carrying type. The two types are bound to differ as widely as the destroyer differs from a river steamer.

CHAPTER XII.

IN CONCLUSION.

FINALLY, let us for a moment consider the utility of the flying machine when we have got it. For some considerable time it will be in the sporting scientific stage. After that will come the useful stage. It is evident that it cannot be an economical carrier of goods, so it must be confined to rapid transport of passengers and messages and to military purposes. Mr. Lanchester calculates that a flying machine will compare, reckoning power for load, with hauling a sledge instead of rolling the load on wheels, because flying at an angle of, say, 1 in 10 is equivalent to constantly climbing a hill of that gradient. Mr. Weiss says that when we really know how to design our machines, and how to make the best use of air currents, we shall be able to fly with little more power than is necessary to push a bicycle (speed for speed). Probably practice will work out between the two theories. Meantime, flying is going to be excellent sport, and a useful hobby for rich men who take their sport vicariously. Every member of the community should take an intelligent interest in the subject, from a national point of view, for the air has no frontiers, and our national existence may ultimately depend on our aerial fleets, and therefore I commend to the attention of all readers of these notes the three leading British flying associations, the Aero Club of Great Britain (166, Piccadilly, W.), the Aeronautical Society of Great Britain (53, Victoria Street, Westminster, W.), and the Aeroplane Club (Savoy Hotel, Strand, W.C.) The secretaries of these societies will be glad to send particulars of their aims and objects to anyone interested in flying, and the subscriptions, which are very moderate, are largely applied to advancing the science of flying by maintaining trial grounds, paying for premises where lectures are given on the subject, and so forth. There are also a number

IN CONCLUSION (Continued).

of provincial clubs, which have been brought into existence through the enterprise of *The Aero*. For purely patriotic, as apart from experimental, purposes there is also the Aerial League, Carlton House, Regent Street, W. It is in reality one's duty to the country to belong to one or other of them, and my best reward for writing these articles is the hope that I may have interested some few readers sufficiently to induce them to join one of these societies and pursue this fascinating subject more deeply.

In revising "Flying" for this second impression, it is satisfactory to note that no alterations have been necessary in the text as originally published, consequently it can be claimed that no one has been misled by what I have written. There has been a good deal of expansion of certain points, and some fresh points have been added, but, in spite of the invitation of criticism, nothing has been shown to be wrong in the text.

In conclusion, I wish to express my indebtedness to Mr. Horatio Phillips and Mr. José Weiss for their pamphlets on flying (these pamphlets having been published for private circulation), and to Mr. Weiss for information and demonstrations given personally; also to Sir Hiram Maxim's and Mr. F. W. Lanchester's books on the subject; also to Mr. Howard Wright and Mr. W. O. Manning, his able lieutenant, for many lucid explanations of matters beyond my unmathematical mind; and to Mr. Harold Perrin (secretary of the Aero Club) and Colonel J. D. Fullerton (secretary of the Aeronautical Society) for general information. To these must now be added Mr. Harold Piffard, Mr. Patrick Y. Alexander, Dr. Albert Zahm (of Washington), and Professor Octave Chanute (of Chicago), who has, by his kindly advice and appreciation, encouraged me to extend this revision of "Flying" considerably further than I should otherwise have done.

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